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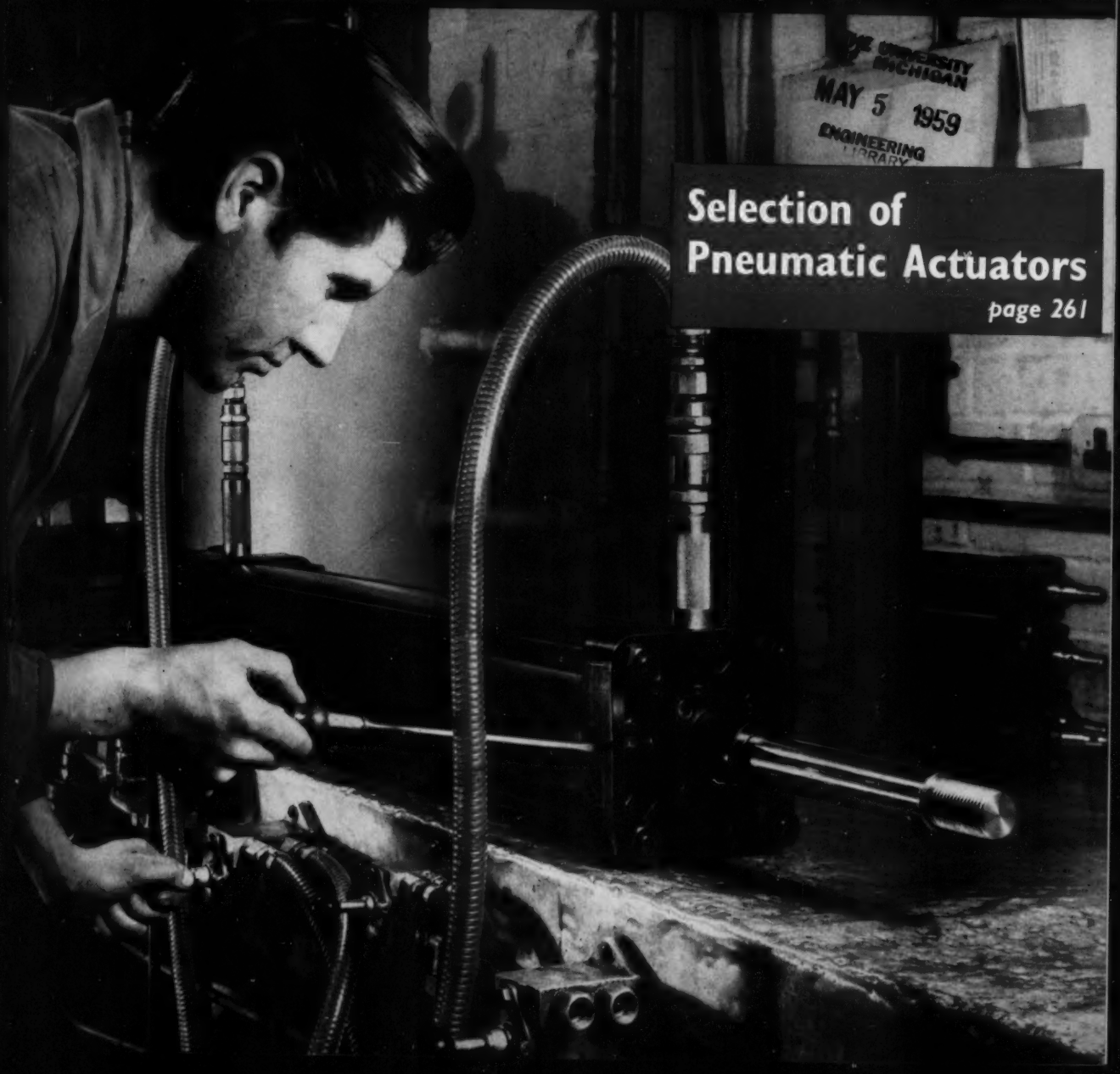
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Selection of Pneumatic Actuators

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Engineering Materials and Design

★ *The Magazine for Engineering Designers*

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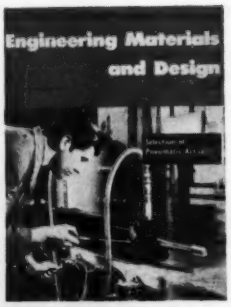

COVER—An operator adjusts the cushioning in a double-acting pneumatic cylinder at the works of Martonair Ltd.

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W42

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Graphite Developments

IT IS EXPECTED that from about 1965 onwards the reactors for nuclear power stations will be based on the advanced gas-cooled reactor (A.G.R.) using uranium oxide fuel and beryllium instead of magnesium cans. This will permit higher operating temperatures and heat ratings and consequently will lead to greater efficiencies than can be achieved in the reactors currently being built for the electricity authorities. The importance of continued reactor development lies in the very competitive nature of present-day reactor design. With the large programme of nuclear power installation in the U.K., even a slight improvement in efficiency brings appreciable returns.

It is therefore interesting to note the developments in the use of graphite as a possible material for enclosing fuel elements. Beryllium is stated to be satisfactory at temperatures up to 600 deg. C., but an A.G.R. employing graphite cans is potentially capable of operating at temperatures above 1,000 deg. C. One of the problems originally encountered was to overcome the well-known porosity of ordinary graphite which would allow leakage of fission product into the coolant gas. A special impregnation process has been developed by the Hawker Siddeley Nuclear Power Co. and by the General Electric Co. for reducing the permeability by several orders of magnitude. This treated graphite would appear to have interesting applications outside the nuclear field for high-temperature gas-tight seals, for example, in gas turbines and the chemical industry, as well as for heat exchangers.

Steel Casting Developments

RECENT IMPORTANT DEVELOPMENTS of a new casting process resulting in a complete change in the moulding and coring methods promise to offer substantially reduced machining costs and may even eliminate machining of parts which are at present accepted with a rough machined finish.

For many years special drying oils have been used in foundries as a sand binder. Research by the Alston Foundry Co. has now yielded a substance which is a carefully-controlled combination of resins and oils with outstanding self-drying or self-curing properties. From this, a patented compound has been developed which, when applied in a predetermined and controlled manner, is said to eliminate drying by chemical action. Results obtained from the use of this process have shown that finer grain sand mixes can be used for both moulds and cores, thereby imparting to the casting a surface finish greatly superior to that of castings made by conventional means. This, combined with the excellent strip, reduces dressing to an absolute minimum, so that castings are said to be substantially free from hard spots normally arising from sand inclusions and fettling processes.

New Thermoplastics

MANY OF THE MATERIALS to be shown at the International Plastics Exhibition to be held at Olympia next month will be improved and more diversified grades of well-established plastics, but among materials recently introduced in the U.K. will be polypropylene. The development of this material promises to be one of the most far-reaching and important and at least two firms will be displaying polypropylene materials. At the International Plastics Convention, to be run concurrently with the exhibition, will be a discussion on the properties and moulding characteristics of polypropylene.

This new plastics, which is another member of the polyolefin group, is similar in many of its properties and appearance to the higher-density polyethylenes, but it is claimed to be lighter, more rigid and resistant to higher temperatures. Although polypropylene is still a new material in terms of commercial use, it is available in the U.S.A. for moulding and extrusion as well as in the form of sheet, fibre and film. Some of the uses to which this material is expected to be put include pipes and fittings, parts for domestic appliances, electrical components such as instrument casings and housings, and parts involving sliding contact such as cams and gears.

Production of polypropylene film is now being studied by the Radio Components Research and Development Committee of the Ministry of Supply. It has been found that the toughness and good flow properties enable thinner films to be extruded by the lay-flat process than with polyethylene. Films down to 0.15 thou. thickness have been made and solution casting with the aim of even thinner films is also under investigation.

Rare-earth Oxide Cathodes

INTEREST IS GROWING in the possible use of rare-earth oxides as cathodes in high-voltage pulsed tubes. The conventional barium-strontium oxide cathode has proved most efficient in tubes that operate at lower voltages; but at higher voltages, as used in magnetrons, cathodes constructed of barium-strontium oxide mixtures tend to tear and spark.

Recent studies at the Battelle Memorial Institute have revealed much about the electron-emission characteristics of oxides of most of the 4-f series of rare-earth elements. It is reported that several of the oxides and specific mixtures of oxides show promise as emitters; they give up to several amperes per square centimetre at temperatures of about 1,400 deg. C. Some of their properties, such as high resistance to sparking, also point to possible usefulness in high-voltage devices. Among the promising materials are gadolinium dysprosium, yttrium (not a "rare earth") and neodymium oxides. However, it is believed that mixtures of two or more oxides are probably more promising.

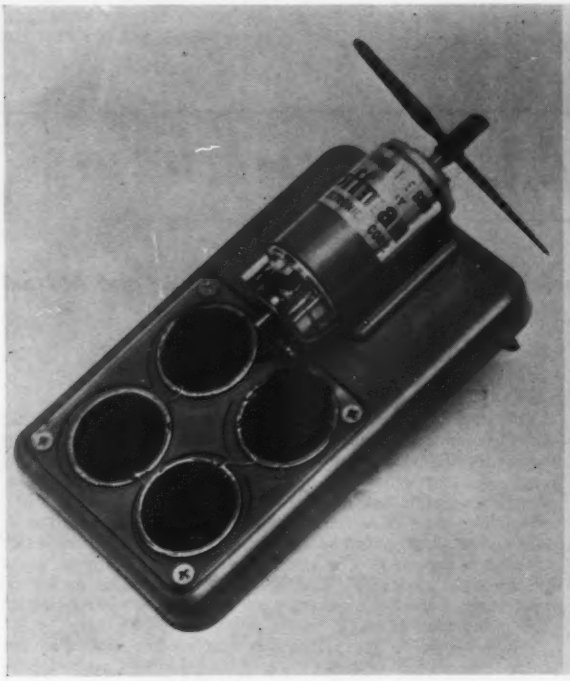
Much knowledge on the properties of rare-earth-oxide cathodes is still needed. Little is known about such important matters as the seat of the emission and the nature of the emitting surface. The Institute physicists concerned in the studies conclude that much more will be learned as methods for purifying the rare earths are improved.

Fusion-welded P.T.F.E.

A NEW FABRICATION TECHNIQUE, fusion welding, now allows the assembly of one-piece lengths or configurations of p.t.f.e. at substantially reduced costs. The resultant weld is a pure fluorocarbon with the same heat, chemical and electrical properties as the base material.

The fusion welding process, now being used by the U.S. Gasket Co., is said to remove many size limitations imposed by existing techniques and available equipment. Through the use of welds, one-piece p.t.f.e. gaskets can be fabricated from two or more sections instead of cutting from sheet stock. Solid gaskets, larger than available sheet size, can now be economically manufactured, allowing greater design flexibility and wider application.

The tensile strength and elongation across the weld are said to be excellent and estimated weld tensile factors generally range between 80-90 per cent of unwelded material.

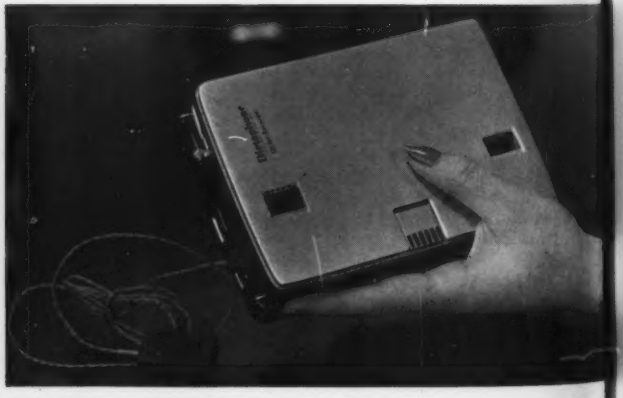


SOLAR ENERGY CONVERTERS

A device demonstrating the direct conversion of light into electricity, through silicon junction solar energy converters, has been developed by Hoffman Electronics Corp. for experimental use in laboratories. It consists of four solar cells wired in series, which activate a small electric motor when exposed to sunlight or a 150-watt incandescent light bulb. The converters are similar to those used to power the radio transmitter of a Vanguard satellite.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN



THREE-POUND TAPE RECORDER

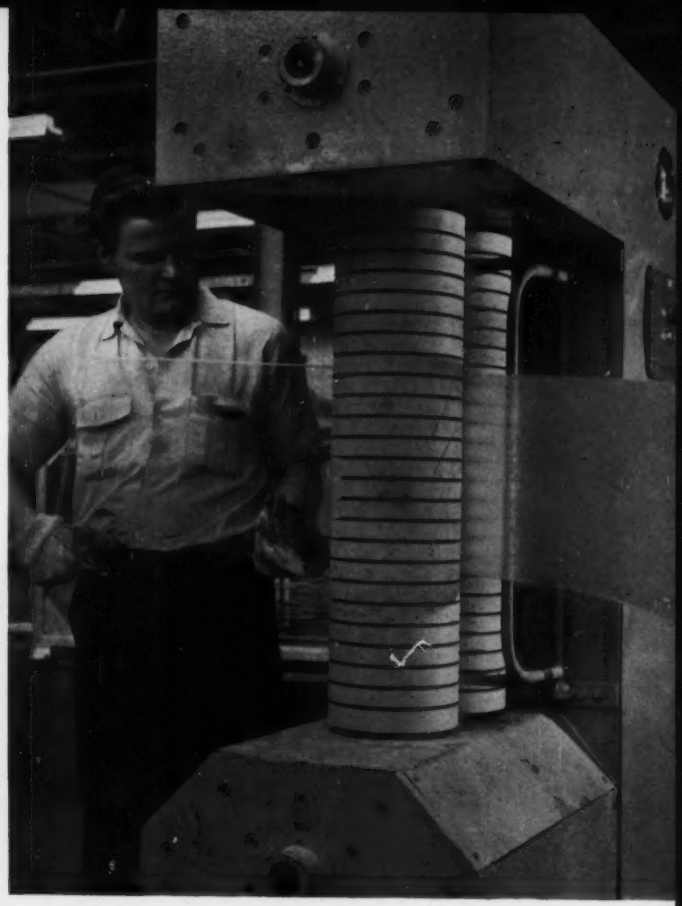
Measuring 2 × 4 × 6 in. and weighing under 3 lb., the Dictet portable tape recorder can carry 60-minute recordings on ¼-in. polyester magnetic tape. Case and magazine are of magnesium, the former having a fabric-base vinyl plastics covering. Power supply is two six-volt mercury batteries for the motor, and a third for a transistor amplifier.

ENCAPSULATING ELECTRICAL COMPONENTS

These three vacuum mixing and pouring plants were designed by E. K. Cole Ltd. for encapsulating electrical components using Araldite resins and hardeners. Ingredients mixed in the conical vessels above are directed through pouring spouts to the components which are arranged in their moulds on a heated turntable, visible through the window to the operator.

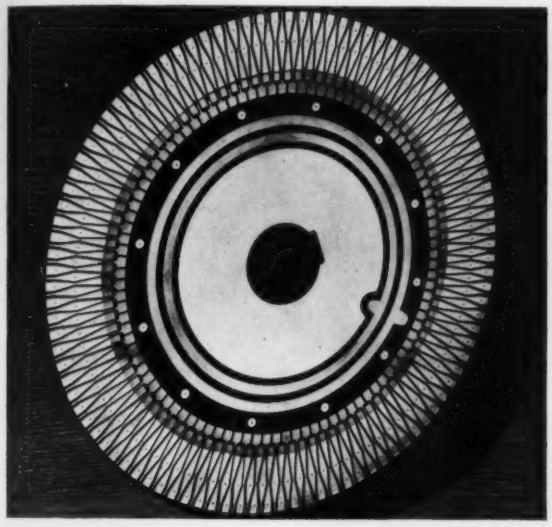
ROLLING LAMINATED GLASS

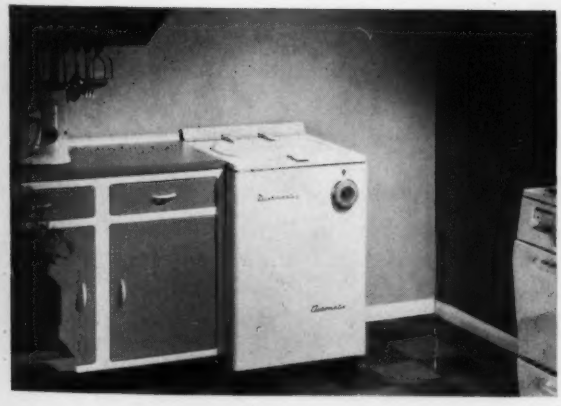
Polyvinyl butyral is used for the adhesive internal layer of Triplex laminated screen which is seen here, assembled and heated, being passed through rubber rollers to provide preliminary adhesion. The part on the right moving towards the rollers is still opaque. After this process final adhesion and clarity are achieved by means of an autoclave.

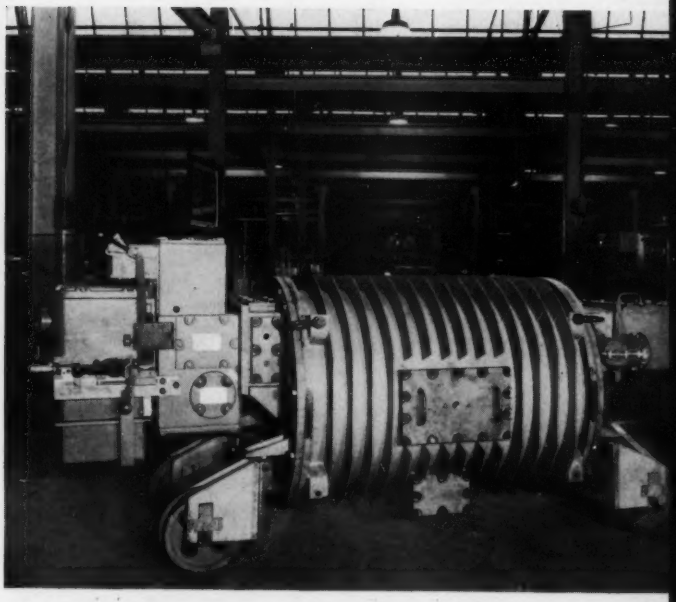


RHODIUM-PLATED PRINTED CIRCUITS

Electro-deposited rhodium is generally accepted as the most satisfactory means of providing multi-way switches with wear-resistant, tarnish-free contact surfaces. This 9-in. stator of a 200-way switch has been designed for use in telemetry equipment. The rhodium has been deposited on the contact surfaces of the 200 sectors as well as on the two slip rings in the centre. Originally the stator had an outside band of copper linking the sectors, as well as a connecting strip to the two slip rings, to permit plating. (Photo: Johnson, Matthey & Co.)







AUTOMATIC DISHWASHER

Latest example of automatic kitchen equipment is this new Kenwood dishwasher, which can be preset by means of a master control knob to wash for a predetermined time, drain the dirty water, rinse with clean hot water for two minutes, drain again and give a second rinse. It then power dries and switches off. It is available in white or cream vitreous enamel.

AWARD FOR TRANSFORMER

An award at this year's Electrical Engineers' Exhibition has been made to the Brush Electrical Engineering Co. for this new dry-type flameproof mining transformer. The award was made on the basis of originality, design and construction, standard of workmanship, labour-saving properties and ease of operation and maintenance. The unit has an output of 300 kVA., 3-phase, 3,300/565 volts.

Silicon for Rectifiers

ALTHOUGH germanium has been used for several years in the manufacture of a great many semi-conductor devices, it is clear that silicon is becoming the preferred material for rectifiers, as it has a greater stability at high temperatures, a higher reverse voltage rating and it operates with smaller reverse currents. Until recently much of the silicon used in the U.K. has been imported from the U.S.A. or France and, although compounds of silicon comprise the main constituents of the earth's crust, the material required for semi-conductors must be of extreme purity, as even a few parts in one thousand million of impurity are sufficient to spoil the semi-conductor properties. A statement by I.C.I. reveals that lump silicon of resistivity greater than 200 ohm. cm. is now available in this country, and silicon in rod form and said to be of exceptionally low boron content is being produced in limited quantities in lengths of 24 in. and diameters up to 1 in. Plans are also being laid to supply silicon in rod form already zone refined into single crystal rods.

A new semi-conductor rectifier that can operate at 700 deg. C. has been announced by Westinghouse in the U.S.A. This rectifier is made of silicon carbide and it is believed that no other known semi-conductor device can function at such a high temperature.

Design of Hydraulic Relief Valves

A PROMISING METHOD is being developed by the Mechanical Engineering Research Laboratory to provide hydraulic engineers with the basic data needed to design relief valves with a given performance.

A relief valve should open at a pre-set pressure, it should open as quickly as possible without imposing shock loads on the circuit, and it should not oscillate and cause noise while it is open. Tests on eight commercial valves showed that the circuit in which the valve is used has a very marked effect on its characteristics. Under the test conditions, none of these valves met all the above requirements satisfactorily.

The method being tried out at M.E.R.L. is to simulate electrically the characteristics of the components of a hydraulic circuit. For example, the orifice of a valve can be considered as a resistance, and the mass of fluid above the valve piston as an inductance. Calculations have been carried out for the electrical equivalent of a simple, but typical circuit consisting of a supply tank, a positive-displacement pump, and a flow-control valve, with the relief valve between the pump and the control valve. The circuit equations indicate whether the valve is adequately damped and give the correct stroke for a given rate of flow; the response time of the circuit can also be derived.

Measurements on this type of hydraulic circuit have confirmed that this electrical analogy method gives valuable guidance to the designer. The method is being developed to cover more complex circuits.

Polystyrene Containers for Liquid Air

APPLICATIONS of polystyrene as a heat-insulating material and for vessels for containing liquid air have recently been investigated at the Czechoslovak Institute of Nuclear Physics, according to a reprint in *Kiglorod*. Glass Dewar flasks are dangerous because of the possibility of cracking, and metal Dewar flasks, though safer, are not a satisfactory substitute for the glass flasks. Unbreakable vessels made of foam polystyrene were, however, found to be satisfactory for the storage and handling of liquid air. The results obtained in the studies made make it possible to assume that foam polystyrene will find extensive application not only as a material for laboratory equpment, but also as an insulating material for low-temperature industrial installations.

Plastics for Corrosion Resistance

THE USE OF METALS for the construction of tanks, pump housings, fan castings, etc., even when heavily coated or lined, has always left the problem, frequently extremely serious, of ultimate penetration of the coating. Where metals have been used as shells the serious danger of unseen corrosion leading to sudden failure has made the continued use of this type of construction undesirable. In addition, the exterior of the tank has been vulnerable to corrosive atmosphere and splash.

In the past, the use of unplasticised p.v.c. has not been entirely successful because of its high price and lack of physical strength. Expanded metal reinforcements have been tried but the danger of unseen corrosion still exists. The use of a plasticised layer to hold the metal reinforcement has not been favoured as the plasticiser is liable to migrate into the unplasticised layer and this fault is also encountered by combining sheets of plasticised and unplasticised p.v.c.

A new approach to the problem announced by Crawley Plastics Ltd. excludes the use of metal as a reinforcement, thus eliminating the chance of voids in the layer but makes use of the chemical resistance of unplasticised p.v.c. at temperatures up to 100 deg. C. The new process depends upon a patented method of chemically bonding unplasticised p.v.c. and polyester resin. Glass fibre is incorporated into the polyester resin to provide the necessary physical strength, and the interior may be lined with p.v.c. to provide the highest degree of chemical resistance. It is claimed that this process can be successfully used for high-temperature ducting up to 100 deg. C. and is said to have given more satisfactory results than high-density polyethylene for this application.

Iron-carbon Batteries

AN IRON-CARBON BATTERY with alkaline electrolyte and electrodes of activated carbon and spongy iron has been developed in the U.S.S.R. at the All-Union Scientific Research Institute of Current Sources. The battery, which is designated VDZh-400, can be used for filament heating of battery receivers, in signalling and communication systems, lighting, automatic blocking on railways, etc. The carbon electrode is prepared by pressing a mixture of activated charcoal wetted with a solution of cautchouc in benzine and paraffin.

The battery, weighing about 5 kg., is said to have an average discharge current of 0·5 amp., a maximum discharge of 1 amp. and a capacity of about 400 amp. hr.

Aluminium-sheathed Cables

DRAWN SEAMLESS ALUMINIUM SHEATHS for telephone cables are being used in the current electrification programme of British Railways for the Manchester-Crewe system. Produced by B.I.C.C., the cables are sheathed with aluminium and provided with heavy steel tapes for electromagnetic screening against induction from the 50 c/s a.c. traction system.

The use of aluminium sheathing is relatively new, and they are now being used for the first time on railways in the U.K.

FOR MORE INFORMATION:

Hawker Siddeley Nuclear Power Co. Ltd., Sutton Lane, Langley, Bucks.
G.E.C. Ltd., Magnet House, Kingsway, London, W.C.2.
Alston Foundry Co. Ltd., Alston, Cumberland.
International Plastics Exhibition, Dorset House, Stamford Street, London, S.E.1.
Crawley Plastics Ltd., Weylock Works, Byfleet Road, New Haw, Weybridge, Surrey.
U.S. Gasket Co., Camden, 1, N.J., U.S.A.
I.C.I. Ltd., Imperial Chemicals House, Millbank, London, S.W.1.
Westinghouse Electric Corp., 3 Gateway Center, P.O. Box 2278, Pittsburgh, 30, Pa., U.S.A.
Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.
Kiglorod, *Moscow. September-October* 1958, *pp.* 62-64.
Battelle Institute Ltd., 24 Ryder Street, London, S.W.1.
"*Iron-carbon Battery*". Radio, *Moscow. December* 1958, *pp.* 45-46.
B.I.C.C. Ltd., 21 Bloomsbury Street, London, W.C.1.

IN NEXT MONTH'S ISSUE

Principal features in the June issue of

ENGINEERING MATERIALS AND DESIGN will include:

Special Uses for Nimonic Alloys
An examination of their particular properties.

Widening Applications for Neoprene
How its flexible properties can help the designer.

Developments in Precision Tubes
New techniques and special applications.

Prevention of Heat and Ice on Windows
Latest methods, including transparent gold film.

Selection of Heat Insulation Materials
A guide to the ranges and varieties available.

Engineering Materials and Design

DEFINING HIGH-TENSILE STEEL

HIGH-TENSILE steel is specified and used by nearly all engineering factories, but an anomalous position arises when the practical engineer, who regards himself as being clearly and intelligently aware of the nature of the materials he is using, quotes the term "high-tensile steel" without having a precise definition of what he means. The term itself has been commonplace in engineering for many years and undoubtedly it has a real and significant local meaning in many organisations. The trouble arises when dealing with suppliers, customers and even colleagues, particularly of a later generation, all of whom may have a different understanding of its meaning. It would appear that it first came into use when steels stronger than mild steel were developed for use in the as-rolled or normalised condition, for the construction of engineering products hardly justifying the use of alloy steels which usually required heat treatment and were relatively expensive.

Until about twenty years ago a steel of 75 t.s.i. U.T.S. was considered to be very high tensile. Ten years ago, D.T.D. 331 and 500 (both since cancelled by B.S. S99) had raised the figure to 90 tons. Today B.S. S28 and 120 have further increased it to 100 tons, which is over sixty per cent greater than when many present-day designers were receiving their early training. In those days a steel entered the "high-tensile" field at a U.T.S. of 40-45 t.s.i. and many engineers seem to find it difficult to readjust their ideas to each advance in materials technology.

Inquiry amongst a number of leading engineers has revealed a surprising variety of opinions as to just what is meant by a high-tensile steel. One reply stated that a steel was high-tensile if it were marked as such. Another suggested that high-tensile steel would be used for a highly stressed part, apparently irrespective of whether the stress involved was tension, compression, bending or shear. A third opinion mentioned that if a steel were high tensile it would be so stated in the specification, but unfortunately this is not always the case. This considerable confusion of thought among highly-skilled practising engineers in positions of responsibility in many fields can and has led to difficulties between those who manufacture the materials, those who design with them and those who use them.

An immediate reaction would be to discard the term "high-tensile steel" altogether and replace it by an appropriate specification number, but there are several reasons why such a suggestion appears to be impracticable. For many purposes it is not necessary to differentiate between more than two or three broad grades of steel. A more precise definition, therefore, only complicates matters, particularly at works level where stores control is involved. Probably the biggest difficulty is that the term "high tensile" has become so firmly ingrained that it would be easier to control by guiding it than by direct opposition.

Some suggestions have been received that a high-tensile steel should have a U.T.S. of 50-70 t.s.i., but for many years it has been found that the U.T.S. of a steel is not a sufficiently accurate indication of its mechanical properties to satisfy the exacting requirements of modern engineering. Even before the Second World War there began to be adopted the standard of the 0·1 per cent proof stress as a more accurate indication of properties. This valuable criterion has now been acknowledged by the B.S.I. to such an extent that it is quoted in the titles of at least six specifications together with the U.T.S., and instead of U.T.S. in the recent S521. The general relationship between the P.S. and the U.T.S. varies according to the material structure and its composition. The former is usually about 15 tons lower, but among the exceptions to this rule are some of the most metallurgically interesting steels.

However, it must be realised that, while it is normal practice in most engineering companies to grade steels on ultimate tensile strength and desirable though it may be from a stress designing point of view to specify at 0.1 per cent proof load, difficulties are likely to arise in the checking of these values particularly in relation to such parts as bolts, studs and nuts where hardness conversion to U.T.S. is commonly used.

Unquestionably the re-classification of steels would be a highly technical and complex problem, but it is not difficult to suggest a principle upon which it could be based. For instance, high-tensile steel could be that steel which has a 0·1 per cent P.S. of 50 t.s.i. or over. Low-tensile could be less than 30 t.s.i. and medium-tensile between 30 and 50 t.s.i. In the same way, non-ferrous metals might be graded with the same stress figures but based on a 0·5 per cent P.S. Another factor which should be considered in defining steels is weldability. Originally it was not necessary for high-tensile steels to be weldable, but this is no longer true, so that weldable steels should be distinguished from the higher strength hardened and tempered alloy steels.

In these days of high specialisation, mechanisation and automation, it becomes increasingly important that engineers, designers and metallurgists should speak the same language as the foremen, inspectors and even the operators, who ought to be fully aware of the mechanical properties and therefore abilities of the materials they handle.

The complete interior liner, as well as the door liner, of this Prestcold refrigerator is vacuum-formed from polystyrene sheet.

HOW TO SELECT RIGID THERMOPLASTICS

This article provides a practical comparison of the properties of rigid polyvinyl chloride, toughened polystyrene and rigid polyethylene, and shows how the designer can suitably employ them.

by D. A. LANNON, B.Sc.*

WITH the increasing use of plastics materials in a wide variety of fields, much interest is being shown in using their special properties in engineering applications. In this article, a comparison is drawn between the properties and applications of three of the most widely used types of rigid thermoplastic materials: namely, rigid p.v.c., rigid polyethylene and toughened polystyrene. The place of plastics in engineering and their properties have been discussed at length elsewhere.[1, 2, 3, 4, 5, 9]

The essential property that these three thermoplastic materials share is their resistance to chemical attack, and especially to corrosion, and it is this property that makes their use in constructional engineering so attractive. In designing to take advantage of this corrosion resistance, however, it is very important to recognise the limitations of these materials. For example, these materials soften if heated to temperatures above 70-100 deg. C. and exposure to direct sunlight can cause serious degradation in the properties of rigid polyethylene and toughened polystyrene. If suitable protective additives are included in their formulations, however, the resistance of these materials to degradation by the ultra-violet components of sunlight is excellent. Rigid p.v.c. has inherently good resistance to outdoor exposure.

Other advantages possessed by these materials are their light weight, good dimensional stability, unlimited colour possibilities and ease of fabrication.

Generally speaking, the materials are available in the form of granules for extrusion or moulding and flat sheet in a large variety of lengths and up to 4 ft. wide for post forming. It is not intended to discuss fabrication techniques in detail, but as the ease of fabrication will affect the cost of using a particular material, reference will be made to the subject at a later stage.

* *British Resin Products Ltd.*

Properties

Tables 1 and 3 show typical physical properties and chemical resistance respectively of the materials under consideration. In addition to normal-impact rigid p.v.c., details are given for high-impact rigid p.v.c., as the properties of these materials are sufficiently different to warrant their separation.

It can be seen that strengths are low when compared with metals, but the comparatively low specific gravities tend to outweigh this. Electrical insulating properties are excellent in all cases, with rigid polyethylene and toughened polystyrene the most outstanding. Resistance to attack by water and moist atmospheres is very high in all cases. As the materials are thermoplastic, their properties vary considerably with temperature. At temperatures below 0 deg. C. brittleness can occur, while above room temperature strength properties are reduced and chemical resistance deteriorates. At temperatures above 70 deg. C., toughened polystyrene softens and loses its shape and rigid polyethylene will do the same at temperatures above 125 deg. C. On the other hand, rigid p.v.c. does not melt as do the other two materials, but it, too, loses its shape under stress at temperatures above about 60 deg. C. The softening points quoted in Table 1 are derived by standard methods which give the temperature at which a standard load will cause a standard deformation, the temperature being steadily and continuously raised until this softening point is reached. As such, the softening point does not bear a direct relation to the maximum service temperature of the materials.

As these materials soften at temperatures above room temperature, their behaviour under constantly applied stress is similar to that of metals near their melting points. Thus, creep can be a big problem in designing plastics structures. The short-term strengths shown in the table

TABLE I. Typical physical properties of rigid p.v.c. and polyethylene and toughened polystyrene.

Property	Normal Impact Rigid P.V.C.	High Impact Rigid P.V.C.	Rigid Polyethylene	Toughened Polystyrene
Density, gm./cc.	1·38–1·42	1·34–1·36	0·94–0·96	1·04–1·06
Tensile strength, p.s.i.	6,500–8,000	5,500–6,500	3,000–5,000	3,000–4,000
Elongation at break, % (0·25 in./min. extension)*	50–200	50–200	200–600	20–40
Modulus of elasticity in tension, p.s.i.	$4–4·5\times10^5$	$3·5\times10^5$	$0·5–1·5\times10^5$	$3–4\times10^5$
Compressive strength (yield), p.s.i.	8,000–9,000	7,000–8,000	2,000–3,000	7,000–8,000
Flexural strength (yield), p.s.i.	10,000–12,000	not applicable	not applicable	5,000–7,000
Impact strength, ft.lb./in. of notch	1·0–3·0	15·0–20·0	2·0–20·0	1·0–3·0
Rockwell hardness	R50	R45	R40	R50
Water absorption, %†	0·05	0·05	0·01	0·05
Volume resistivity, ohm.cm.	10^{16}	10^{14}	10^{17}	10^{17}
Surface resistivity, ohm	10^{15}	10^{15}	10^{19}	10^{19}
Power factor @ 50 c.p.s.	0·01	0·03	0·0001	0·0004
@ 10^6 c.p.s.	0·02	0·04	0·0001	0·0005
Dielectric constant				
@ 50 c.p.s.	3·7	3·9	2·35	2·55
@ 10^6 c.p.s.	3·3	3·5	2·35	2·55
Electric strength,‡ volts/mil. @ 23°C.	450	450	575	575
Softening point				
°C. (ASTM)	70–75	65–70	70–75	70–75
°C. (Vicat)	70–75	65–70	110–125	80–85
°C. (BS.1493)	75–80	70–75	110–125	80–85
Coefficient of linear expansion, per °C	5×10^{-5}	10×10^{-5}	13×10^{-5}	7×10^{-5}
Thermal conductivity cal./sec./cm.²/°C./cm.	4×10^{-4}	5×10^{-4}	12×10^{-4}	2×10^{-4}
Specific heat	0·25	0·25	0·40	0·32

*Mostly cold drawn. †2 in. × ⅛ in. disc 24 hours at 23°C. ‡Step-by-step test as B.S. 2782.

have to be reduced by two-thirds to three-quarters when assessing long-term load-bearing properties. Rigid polyethylene can suffer from brittle failure under certain conditions of stress and this tendency is accentuated by the presence of certain organic and oxidising chemicals and at elevated temperatures. The typical brittle failure happens quite suddenly with comparatively little prior elongation or strain, and is the main reason for the limit on the maximum long-term tensile stress for rigid polyethylene of about 25 per cent of the short-term tensile strength. The typical failure in rigid p.v.c. and toughened polystyrene is more in the nature of a ductile failure, a comparatively large strain being apparent before breakage occurs. Typical strain-time (creep) curves for the materials are shown in Fig. 1.

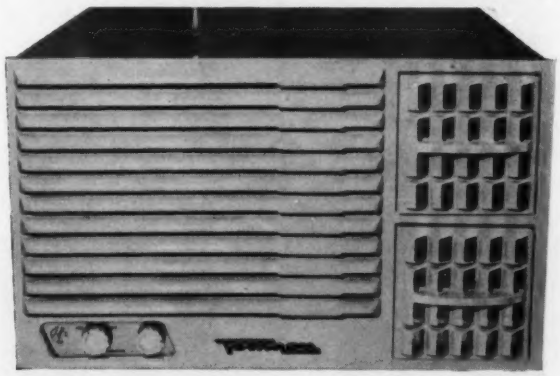
As previously mentioned, these materials can suffer ageing effects on exposure to outdoor conditions. Ageing and embrittlement can also occur at elevated temperatures and materials for use under such circumstances must be specially formulated. Carbon black and titanium dioxide are the usual protective pigments employed when ultraviolet light is to be encountered and a variety of antioxidants and stabilisers are used to protect the materials from the effects of heat.

Rigid P.V.C.

The term p.v.c. usually denotes simple polymers of polyvinylchloride or copolymers of vinyl chloride with vinyl acetate or vinylidene chloride, containing more than 75 per cent of vinyl chloride. For the purposes of this article, rigid p.v.c. can be assumed to be based on a polymer containing at least 90 per cent of vinyl chloride which is compounded to produce the properties needed for a particular application. Toughened or high-impact rigid p.v.c. is a special case in which the basic rigid p.v.c. compound has been modified to increase toughness, especially resistance to shock damage. As can be seen from Tables 1 and 2, other effects are also produced. Toughened rigid p.v.c. has a slightly lower softening temperature, slightly lower tensile strength and slightly inferior chemical resistance to normal-impact rigid p.v.c. The properties of this material are therefore such that it is used where much greater toughness is required and where chemical resistance requirements are not so stringent as those which could be met by normal rigid p.v.c. As more than one of the materials can often be used for a particular application the choice between them must be made on the basis of first cost and the actual properties required, and some indication of overall property/cost considerations is shown in Table 2.[7]

The main uses for these constructional materials in industry are in the form of sheet and tube or pipe and it is to a discussion of these uses that this article is confined.

Rigid p.v.c. piping is widely used in the chemical industry for applications in which steel and copper would quickly corrode. The light weight and ease of installation and maintenance of rigid p.v.c. pipe make it competitive with other corrosion-resisting materials where its temperature limitations do not matter. Pipelines of up to 12 in. in diameter are in regular and extensive use in oilfield and oil refinery installations, carrying clean and waste water, brine and other ancillary services as well as for the transport of crude oils. Such lines are often buried, since soil corrosion is no problem, but surface lines are also



The facia grille of this Temkon air-conditioning unit was vacuum-formed with polystyrene, providing a tough and an attractive finish.

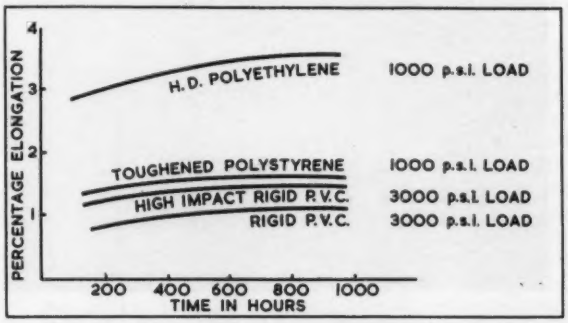


Fig. 1. Typical strain-time (creep) curves for rigid p.v.c., and polyethylene and toughened polystyrene.

TABLE 2. Comparison of merit ratings for rigid thermoplastics

	Rigid P.V.C.	High Impact Rigid P.V.C.	Rigid Polyethylene	Toughened Polystyrene
Material cost	7	6	5	8
Fabrication cost	8	8	8	9
Density	7	7	9	8
Structural strength	6	6	4	4
Resistance to physical damage	7	7	9	6
Temperature resistance	4	4	4	4
Practical index	39	38	39	39
Resistance to solvents	7	7	6	3
" " salts	10	10	10	9
" " alkalis	10	10	10	7
" " acids	10	9	10	8
" " oxidation	9	8	6	3
Chemical resistance index	46	44	42	30
Total index	85	82	81	69

Note: A rating is given for each material for each property, 10 being the most desirable.

frequently used. Similar rigid p.v.c. pipelines have replaced metal pipes in general chemical industry uses where corrosive effluents, both acid and alkaline, have to be safely conveyed.

P.v.c. sheet is used very extensively in the electro-plating industry. Both plating tank linings in which the insulating properties of the material offer an additional advantage and the ductwork used to extract corrosive fumes from the plating shop are frequently constructed from rigid p.v.c. sheeting. These are readily fabricated and far outlast their previously used metallic counterparts. Many other chemical works use systems for extracting acid and other corrosion vapours fabricated from rigid p.v.c. Extractor fans are available for use in such systems in

Part of an acid effluent disposal system made with high-impact rigid p.v.c. and installed at the B.P. refinery on the Isle of Grain.

TABLE 3. Typical chemical resistance properties (for general guidance only)

	Temp. °C.	Normal Impact Rigid P.V.C.	High Impact Rigid P.V.C.	Rigid Polyethylene	Toughened Polystyrene
Acids					
Acetic 20%	20	E	G	E	G
	60	G	F	G	P
Glacial	20	F	P	NR	P
	60	P	NR	NR	NR
Chromic 30%	20	E	G	G	G
	60	G	G	G	P
Hydrochloric 30%	20	E	E	G	G
	60	E	E	G	F
Nitric 30%	20	E	E	G	G
	60	E	E	F	F
Oxalic 10%	20	G	G	E	G
	60	F	F	G	G
Phosphoric 50%	20	E	E	G	G
	60	E	E	G	F
Stearic 100%	20	E	E	G	E
	60	G	G	G	G
Sulphuric 20%	20	E	E	E	G
	60	E	E	E	F
80%	20	E	E	P	NR
	60	E	G	NR	NR
Alcohols					
Butyl	20	E	F	P	G
	60	G	NR	NR	P
Ethyl	20	E	G	G	G
	60	G	NR	P	F
Methyl	20	E	G	G	G
	60	F	P	P	F
Propyl	20	E	G	G	G
	60	G	P	P	G
Alkalis					
Ammonium hydroxide	20	E	E	E	E
(conc.)	60	G	G	G	G
Sodium hydroxide	20	E	E	E	E
(conc.)	60	E	E	G	E
Organic Solvents					
Benzene	20	NR	P	G	NR
	60	NR	NR	NR	NR
Carbon tetrachloride	20	G	NR	G	NR
	60	P	NR	P	NR
Castor oil	20	E	E	E	G
	60	E	G	G	G
Diethylene	20	G	G	E	E
Glycol	60	P	P	E	E
Diethylether	20	P	NR	F	NR
Formaldehyde	20	E	E	E	E
	60	E	G	E	G
Glycerin	20	E	E	E	G
	60	E	E	E	G
Hexane	20	E	P	G	NR
Phenol	20	G	P	E	NR
	60	NR	NR	G	NR
Turpentine	20	E	P	G	NR
	60	E	NR	NR	NR
Petrol and Oils					
Petroleum spirit	20	G	P	E	NR
Motor oil*	20	G	G	G	P
	60	G	P	P	NR
Mineral oil	20	E	E	E	G
	60	G	G	G	P
Hydraulic fluid*	20	G	G	G	F
	60	G	G	F	P
Salt Solutions Normal and high impact rigid p.v.c. and rigid polyethylene show generally excellent properties. Properties of toughened polystyrene range from fair to excellent, except with ferric chloride at 60 deg. C., where its use is not recommended.					

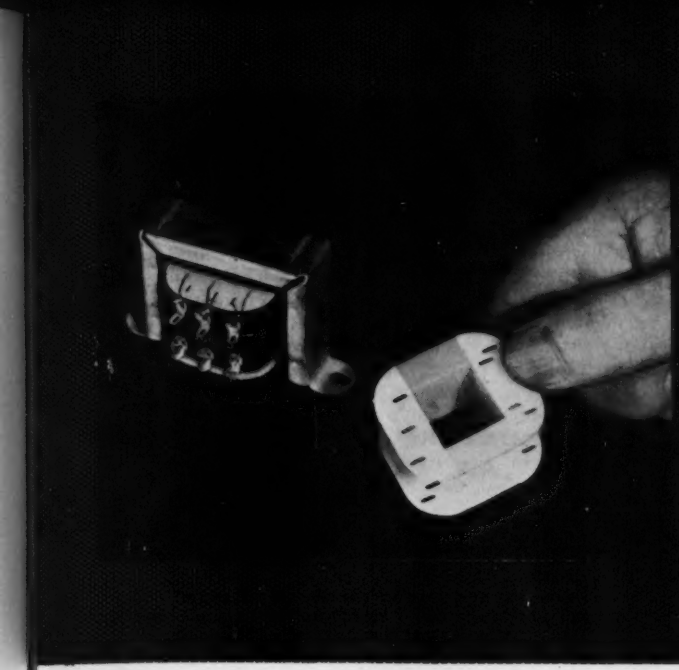
E—Excellent; G—Good; F—Fair (service tests required before use); P—Poor; NR—Not recommended.
*Depends on type; each product should be tested.

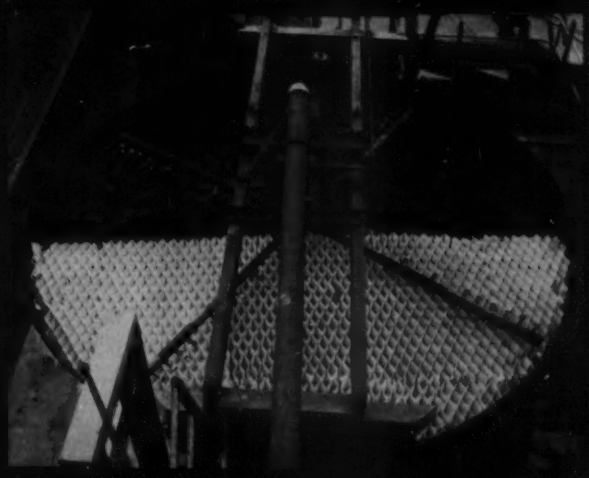
which the exposed parts are made from or protected by rigid p.v.c. Large-bore extruded tube can be used in this application.

Other industrial uses are in the form of extrusions, roof gutters and down pipes, electrical conduit and busbar insulation, and in the form of fabricated sheet, transparent signal relay covers, vessel linings and, more recently, transparent roof lights, especially in corrosive situations.

Rigid Polyethylene

It can be seen from Tables 1 and 3 that the material has a low density and is very tough. It is not available in transparent form, being milky white and translucent in unpigmented form, and it must, for outdoor use, be protected from ultra-violet light by the use of carbon black. It has excellent electrical insulating properties and is widely used in radio-frequency electrical applications where its very low power factor and dielectric constant are of great importance.





One of the limitations of the material is its so-called "stress cracking", i.e., its tendency to failure under conditions of stress when in contact with certain liquids such as detergents. This tendency becomes more marked as the temperature is raised. The strength properties of rigid polyethylene and its resistance to stress cracking are a function of the molecular weight and molecular structure of the material, highest impact strengths and greatest resistance to stress cracking being obtained with materials of highest molecular weights.[6] However, the higher the molecular weight, the more difficult the material becomes to fabricate, and a balance has to be struck to obtain a reasonable compromise between these conflicting requirements.

Pipes made from rigid polyethylene are mostly used for water services, and both potable and service water lines are increasingly fabricated from this material. Other rigid polyethylene pipes have been installed for the conveyance of salts, mild acids and similar liquids. The food industries are also showing great interest in this material for liquid transfer applications and as vessel linings.

Rigid polyethylene sheet is one of the more recent additions to the field of corrosion-resisting materials for ductwork and tank lining and its possibilities are being closely examined by designers of fume extraction systems where a certain amount of structural strength as well as good chemical resistance are required.

Containers for corrosive chemicals which need no protective outer cover are also fabricated from rigid polyethylene.

Toughened Polystyrene

Toughened polystyrene is slightly less tough than the other materials considered here and is less resistant to organic solvents, but in other respects compares very favourably. In its natural unpigmented form it is a milky white translucent material and is therefore available in a wide range of light and dark colours. It is probably the easiest material to fabricate of those being considered here.

Only comparatively small quantities of toughened polystyrene pipe are used in industrial applications, mostly for oilfield and other uses in the conveyance of solutions of salts and mild acids and alkalis.

Ductwork fabricated from toughened polystyrene sheet is extensively used for air conditioning in chemical and textile industries[8] and tote boxes formed from toughened polystyrene sheet are also used. An interesting application, known as Dowpac, is the use of specially formed sheets in scrubbing towers and filter packs in place of conventional materials such as stone. Greatly improved efficiencies have been demonstrated for this technique, mainly in the form of better throughput for a given pressure drop and a reduction of the tendency to fouling.[5] The design of the sheets is such that they nest easily for convenient transport and storage.

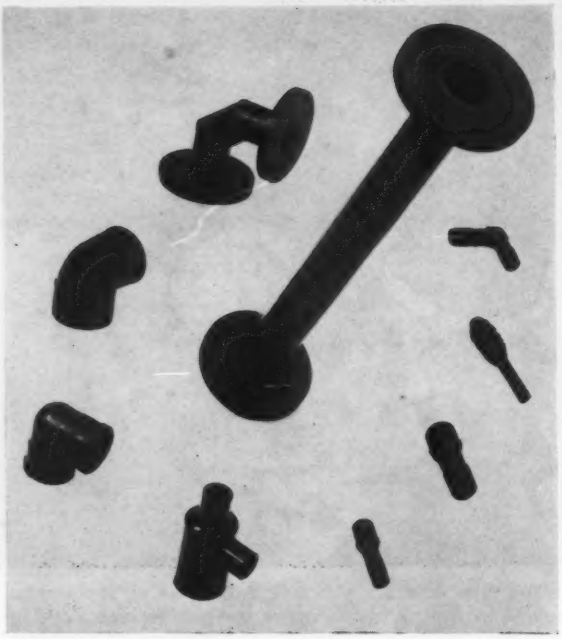
Fabrication

All three types of material are readily formed by screw extrusion into sheet, pipe and other sections. Rigid polyethylene and toughened polystyrene are relatively much easier to process by this technique than rigid p.v.c. and this can affect the cost to the user quite considerably. Some sheet, especially rigid p.v.c., is also formed by calendering the material into thin sheets (about 0·005-0·015 in.) and laminating these to the required thickness by a compression moulding process. This, of course, is a comparatively expensive method.

Sheets are usually supplied in dimensions up to 8 ft. by 4 ft., though larger sizes are sometimes obtainable. Pipes up to 24 in. in diameter are available and these are usually supplied in standard cut lengths of up to 20 ft. Rigid p.v.c. pipe and sheets can be readily formed or joined by well-established processes. The pipe joints are very often made by solvent welding or by the use of adhesives, though threaded couplings are sometimes used. Threads in rigid p.v.c. can cause weaknesses, however, owing to the notch sensitivity of the normal impact material, and an adequate wall thickness must be allowed if this technique is to be used.

Rigid p.v.c. pipe can be readily bent by immersing it in boiling water until it softens slightly, and carefully bending to shape. The pipe or sheet can be machined, with slight modifications to the equipment, by the usual methods. Drilling, sawing and stamping can also be easily accomplished. Large tanks, ducts, etc., are usually fabricated by hot gas welding, nitrogen being the usual gas; the welds can give strengths of the same order as those of the base material. If lower strengths are acceptable solvent welding can be used. A fuller description of fabricating techniques is given by Mottram and Lever.[2]

No solvent suitable as an adhesive for polyethylene is available, and jointing of pipe has therefore to be carried out by mechanical methods such as compression joints, as



Examples of pipes and pipe joints produced in rigid polyethylene.

used with copper, or flange-type joints. Hot gas (nitrogen) welding techniques similar to those used for rigid p.v.c. are suitable for fabricating ductwork, tanks and other large articles from rigid polyethylene. It must be emphasised, however, that welding of thermoplastics, as with all forms of welding, is a skilled job which must be carried out with great care if satisfactory results are to be obtained.[10] Machining is as for rigid p.v.c.

Toughened polystyrene joints are almost invariably made by solvent welding or adhesive bonding, as a large variety of common organic solvents, either alone or containing small quantities of dissolved toughened polystyrene, give excellent bonds. Such solvent welds would probably be unsuitable for vacuum applications, however, and hot gas welding would be used here.

Finally, a process common to all three types of material in sheet form is low-pressure forming either by vacuum, air pressure or matched metal moulds. Many medium and large sized articles are produced by these techniques by which finely-detailed articles can be produced with cheap moulds, making comparatively short runs reasonably economic. The details of the processes vary slightly with the materials used, but, briefly, a heat-softened sheet is clamped over a mould and vacuum or air pressure is used to force the sheet to take the shape of the mould.

Choice of Material

It can be seen that in many cases the choice of material must be based largely on the physical and chemical properties required and on the relative cost of the fabricated item. Thus, for example, normal-impact rigid p.v.c. will be the natural choice if outstanding chemical resistance and resistance to ageing are required, because of the tendency of rigid polyethylene to suffer from stress cracking in certain environments, and because toughened rigid p.v.c. and toughened polystyrene have generally poorer chemical resistance. Higher temperature applications would tend to give rigid polyethylene the advantage, though rigid p.v.c. can be used if no applied stress is involved.

However, if no such obvious consideration is involved, the choice can be made on a basis of a summary of the three factors, price, physical and chemical properties. A useful method of arriving at such a summary is shown in Table 2, where a "practical index" and a "chemical resistance index" are summarised and added to give a "total index". A rating applying to each material for each of the factors involved is shown, 10 being the most desirable. It must be made quite clear, however, that in any new application the manufacturers of the material should be consulted and their recommendations followed, in order that the potentialities of these materials can be utilised to the full.

The three thermoplastic materials, rigid p.v.c., rigid polyethylene and toughened polystyrene, can be valuable materials of construction, particularly where corrosion is a problem. Despite their limitations of comparatively low long-term strength and poor high-temperature resistance, in selected applications they have been proved to be by far the most suitable materials at present available.

REFERENCES

1. Symposium on Plastics as Materials of Construction. Cooper *et al.*, *Ind. Eng. Chem.*, **47** (1955), pp. 1292 *et seq.*
2. "Unplasticised P.V.C. as a Constructional Material in Chemical Engineering". Mottram and Lever, *Industrial Chemist*, **33** (1957), pp. 62-67, 123-128, 177-180 and 241-245.
3. "New Developments in High-density Polyethylene". Muirhead. *Engineering Materials and Design*, **1**. pp. 35-38.
4. "Modified Styrenes for Structural Applications". Steiner. *Ind Eng. Chem.*, **47** (1955), pp. 1307-1311.
5. "Plastics in Heavy Chemical Plants". Griess. *Ind. Eng. Chem.*, **47** (1955), pp. 1343-1349.
6. "Factors Influencing Long-term Stress Properties in Polyethylenes". Reid, Pritchard and Reynolds. *Plastics Progress* (London), 1957, pp. 59-71.
7. "High Impact Rigid Vinyl Materials". Parks and Jennings. *Plastics Progress* (London), 1957, pp. 109-127.
8. "Engineering Plastics into Chemical Plants". Atkinson. *Ind Eng. Chem.*, **47** (1955), pp. 1299-1304.
9. "Use of Vinyl Resins in the Construction of Chemical Plant". Martin. Proceedings of Corrosion Convention (London) 1957.
10. "Welding of Plastics". Haim and Zade, H. P. (Cleveland), 1954.

BRITAIN'S PACKAGE-SIZE NUCLEAR REACTOR

IN September of this year, the first British package-size nuclear reactor will be in operation at the Langley works of the Hawker Siddeley Nuclear Power Co. Ltd. Designed initially as a training reactor, Jason (as it is called) can be used for lattice experiments and detecting true elements in amounts as low as 10^{-12} gm., as a source of neutrons for activation experiments and for general research work.

This 10-kW. project is an inherently safe water-moderated type using aluminium-clad fuel elements of uranium-oxide/aluminium mixture and at a capital cost of £50,000 represents a comparatively cheap reactor. For training purposes, it is expected that students will carry out their practical studies at Langley, but a number of inquiries from universities, colleges and industrial concerns in many parts of the world suggest that Jason may be the first of many to be produced there.

In their investigations into the corrosive effects of coolants, both gases and liquid metals such as bismuth, sodium and lithium have been studied. As the result of certain of these investigations, the company have perfected a method of laying a thin adherent non-porous coating of a refractory metal on the interior surface of tubes.

Other experimental work undertaken at Langley has been the development of graphite fuel element containers and an ultimate safety device. This latter effectively poisons the system and stops the reaction when a power surge increases the temperature of a fuel element at a rate which cannot be matched by the normal control rod operation. The value of this device lies in its instantaneous operation and the fact that it is necessary only to replace the affected element.

NOISE – ITS NATURE, BEHAVIOUR AND REDUCTION

The second of two articles dealing with effective noise control in the design of engineering products. This part examines human reaction and tolerance to noise and practical silencing techniques that can be employed

by D. M. A. MERCER, M.A., B.Sc.*

IT is possible at this stage to begin on the fundamentals of controlling noise, involving initially an understanding of the correct function and application of sound-absorbing materials.

Fig. 2 may be used to indicate the range of usefulness of acoustic absorbing materials, i.e., glass fibre, rockwool, acoustic tile, etc. In the case of the example dealt with on the final page of the first part of this article (see page 198, *E.M.D.*, April issue), i.e., a room with R = 1,000, this was calculated for an average absorption coefficient of 0·1, a fair average for such factory enclosures.

By the use of a good deal of acoustic material, we may be able to bring the average absorption coefficient up to 0·4, giving R = 6,500, about. In the diffuse field, however, this gives a reduction of only about 8 dB., a noticeable but not substantial improvement. Five feet from the source the reduction would be only about 3 dB., a negligible amount.

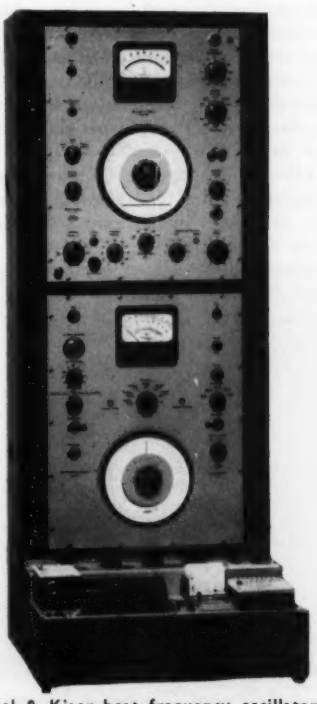


Fig. 1. Bruel & Kjaer beat frequency oscillator, an audio frequency spectrometer type 2110 and a level recorder type 2304, mounted together.

This example demonstrates the fact that the law of diminishing returns soon sets in when absorbing material is used, and generally it is unnecessary to try to cover every small area of wall or ceiling with it.

The problem may be looked at in another way. If the walls were completely covered with perfect absorbent, it would be the same situation as if the noise source were in free space. Would it then be audible on standing near it? The evident fact that it would indicates the limitations of acoustic absorbent material.

An efficient use of such material is often to use it near the source. Functional absorbers (spheres or other geometrical shapes) made of acoustic material and suspended from the ceiling are often valuable. These, and absorbing materials generally, are most valuable in a space where there is a distribution of low-level noise sources; in a large drawing-office, for instance, such treatment can be very beneficial.

Sound Transmission Through Structures

Up to now we have considered airborne sound. We now turn to structure-borne sound, i.e., sound transmitted through partitions.

The simple basic case is that of sound waves striking a massive wall, large enough for edge effects to be neglected. The wall will be set into vibration and will in turn act as a source, generating sound waves in the air on the other side.

The basic factor governing the amount of sound transmitted is the weight per unit surface area of the wall. The relation between this and the difference in sound levels on the two sides of the wall, known as the "transmission loss" (abbreviated TL), is shown in Fig. 3. The abscissa indicates that the TL of a wall depends on frequency: its value is found for any frequency by multiplying the frequency by the surface weight of the wall.

"Average" TLs, quoted below, refer to a frequency of about 500 c/s.

The mass of a wall increases very rapidly as high TL is needed. When TLs of greater than about 50 dB. are

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required, it is more economical to split the wall up into two layers, with an air space between. For the same weight of material, a double wall of this type is some 5-10 dB. more effective than a single wall. The same remarks apply to double-glazed windows.

It is worth emphasising the importance of mass, as there is a widespread idea that acoustic absorbing materials will prevent sound being transmitted through them, and often partitions of, say, glass fibre are suggested. This idea may be called the biggest fallacy in the whole business of noise control. The purpose of absorbing materials is only to absorb sound inside an enclosure, as already indicated.

It is not difficult to show why this is so. A good absorbing material may absorb 80 per cent of the incident sound energy, reflect 10 per cent and transmit 10 per cent. But a 4½-in. brick wall will transmit only about 0·01 per cent of the incident energy. The difference between this and 10 per cent, namely 30 dB., represents a very large difference in insulation.

If, say, a noisy machine is at one end of a room, and quiet conditions are needed at the other, the only satisfactory means is to build a partition with sufficient mass. Having done this, acoustic absorbing material may *then* be applied with some advantage to both spaces, each side of the partition. But the general conclusions pointed out above still apply, and the extra reduction is not large.

Behaviour of Practical Structures—Real structures fall below the mass law curve, in certain frequency regions at any rate, for two reasons, both dependent on the stiffness of the wall. One is that if the wall can vibrate like a diaphragm, it will transmit sound very readily at its resonant frequency. The other is the recently discovered "coincidence effect". If bending waves can travel along the wall, it may be possible for their speed to be matched by sound waves falling on the wall at an angle, as shown in Fig. 6; the bending waves will be maintained, and the wall will transmit over a range of frequencies. These two effects are most important for fairly light structures.

Effects of Openings in Partitions—People are often puzzled over the allowable size of holes or cracks in a sound-insulating partition. The treatment is quite simple. Consider a wall with a TL of 30 dB., i.e., it transmits one-thousandth part of the incident energy. Then, to a first approximation, a hole of area of one-thousandth of the partition will transmit the same amount of energy as the partition itself. It should be reduced to at least a quarter of this amount to be negligible.

Similarly, a door in this partition, occupying 10 per cent of its area, with a TL of 20 dB., will transmit the same amount of energy: its TL should be increased to 25-30 dB.

Practical cases can easily be worked out from these examples.

Sound Transmission in Practice—The behaviour of structure-borne sound in a multiple structure is worth study. Fig. 7 is a "classic" diagram showing the possible paths which sound can take from a source in one room to a listener in the other. Path No. 1 is transmission through the partition in the ordinary way. No. 2 is caused by the common outside wall being set into vibration and radiating in the listening room. In 3 this common wall can set the partition vibrating, and in 4 the reverse effect can take place. Finally, if there are windows, 5 shows that sound can travel out by one and in by the other.

If this is understood, it will help with many problems in silencing. For instance, a massive partition may have its effect nullified if the common outer wall can vibrate too freely. A break in the structure at joints is ideal: this is often impracticable, but valuable when it can be done.

Human Tolerance to Noise

We now come to consider the problem of human response to noise, or "psycho-acoustics". This is in general a most complex problem; people's irritation with noise often has little to do with the noise level. Trains and one's own radio are tolerated, but comparable level from aircraft or a neighbour's radio could bring forth complaints.

However, in the case of general industrial noise we may simplify the problem considerably, since response to the average industrial noise is fairly uniform. We may consider the problem under three headings: comfort, communication and deafness.

Noise in Offices—A good deal of work has been done recently on noise criteria for offices.[1] It is found that certain levels should not be exceeded, or either of two things may happen: (a) the noise becomes so loud that people complain (usually of low-frequency sounds), or (b) the higher frequencies become so pronounced that speech communication becomes difficult.

The two curves shown in Fig. 5 give two of many criteria. A noise level below curve A would represent a satisfactory background for a conference office with a 15-ft. table. A noise level up to curve B would mean that people had to be a foot or two away from each other in order to talk properly, and the general noise level would make use of the telephone slightly difficult.

The general effect of noise on annoyance, and hence loss of efficiency at work, is a most difficult one in which no definite conclusions have been reached: although it does seem that excessive noise makes people more fatigued at the end of a day.

Noise in Homes—Annoyance of people in their homes by noises emanating from factories is a rather more complex problem. However, means exist for dealing with this as well. Again the noise level is measured against a set of criterion curves, similar to those mentioned above: but a considerable number of factors have to be taken into account such as the type of noise, its time-pattern, the type of neighbourhood, etc. It is possible to say, however, from

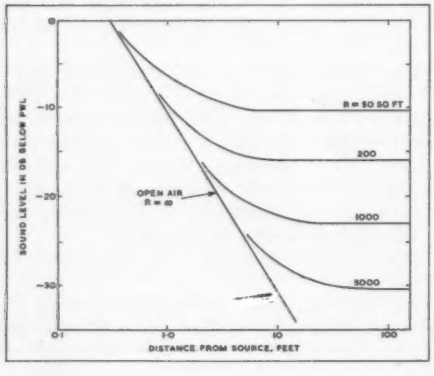


Fig. 2 (*Far left*). Sound level of a source in an enclosure.

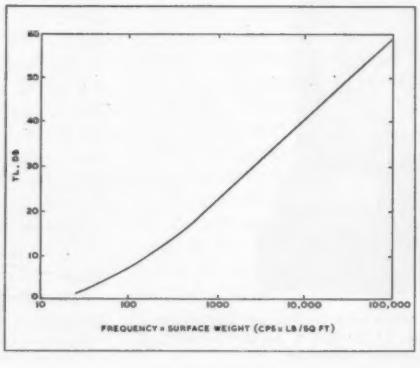


Fig. 3 (*Left*). Mass law curve.

this treatment, how people are likely to react in the average case. This is often valuable when, say, a factory wishes to install new machinery which is known to be noisy; it is possible to say in advance how much silencing will be needed.

SPEECH INTERFERENCE BY NOISE—Interference with speech has, of course, a direct bearing on the working efficiency of people who need to take part in discussions, or who use the telephone. Sound in the region 600-4,800 c/s is most effective in interfering with speech, and the mean of the decibel levels in these three octave bands is taken as a measure of the "speech-interference level". If, for instance, this is 55 dB., it is possible to converse in a normal voice at 3 ft., or raised voice at 6 ft.; this level would be satisfactory for secretarial rooms, control rooms, etc. Similar data are available[2] for other speech interference levels.

NOISE-INDUCED DEAFNESS—It is steadily becoming recognised that excessive noise can cause permanent and irreparable damage to the hearing of those who work in this environment for several years.[3] Definite information at the moment is difficult to obtain, but the most recent conclusions are that if the noise level in any octave band in the mid-range of audible frequencies is over about 90 dB., it is likely to be damaging to hearing over a period of years.

A good deal can be done to mitigate the danger. Of course, the noisy machinery should be silenced whenever possible but, if not, earmuffs or earplugs can be worn by the workpeople. It is wise, too, for the firm to make periodic checks on the hearing of people exposed to intense noise. This can be done with an instrument known as an audiometer, which can be operated by a factory nurse or technician, provided the records are examined by a qualified ear specialist. This means that any person whose hearing is being affected can either be given extra protection, or transferred to a quiet situation, before damage is done.

Structural Failure Due to Noise

We may now consider briefly the effect of noise on engineering structures. Many of the problems are identical with those caused by vibration; parts may become loose, or there may be excessive amplitudes of structures which happen to have resonances at the frequency of the exciting force. But there are, in fact, cases in which noise alone is sufficiently intense to cause metal fatigue. The noise levels have to be really high for this to happen, i.e., comparable to those existing quite near to the exhaust of a jet engine. In aircraft structures exposed to such levels fatigue problems can be serious, resulting in the fracture of small brackets, metal cracks around rivet holes, and so on. Cases of this sort are rare at industrial noise levels, but, say, gas discharges which cause low-frequency "buffeting" should be given careful attention.

DESIGN APPROACH TO PROBLEMS—It cannot be too strongly emphasised that noise suppression should be undertaken in the design stage of a machine or a building. Neglect of this may lead to problems which at best are difficult, with an unsatisfactory solution, and at worst can be virtually impossible to solve. For instance, if a decision were taken to use the upper floor of a two-storey building for machinery, and the lower floor for offices, the problem of noise transmission through the floor into the office space might be almost insuperable, whereas the simple decision to interchange the function of the two floors means that the problem simply would not arise. This example is by no means far-fetched.

A similar type of problem consists of, say, a noisy machine near to a block of offices. Which would be less expensive—to silence the machine thoroughly, or to provide it with a modicum of silencing treatment, and soundproof the office walls and windows? If there are no houses nearby, this may prove to be adequate and less expensive; but, in any case, it is the sort of decision which should be considered.

PRACTICAL SILENCING TECHNIQUES—A short description of the whole field of silencing techniques is rather like a short description of treatment of illness—it is possible only to give a simple outline. However, it is hoped that those who have studied the earlier treatment will recognise the application of basic principles and be able to apply them themselves in a sound way.

The first point is to determine the degree of silencing needed. Silencing treatment is not only usually expensive, but the cost rises logarithmically with the effect, i.e., further equal increments of silencing may cause doubling, and re-doubling of the cost; hence the amount of treatment needed should be determined. At this stage, accurate noise measurements and analysis and careful study of criterion curves are necessary.

The basic technique, to be adopted whenever possible, is to silence the noise producer itself. A noisy automatic lathe may be fitted with a lined stock tube to reduce the noise, a noisy fan may be modified (even at the cost of some blowing efficiency) so that its noise output is less,

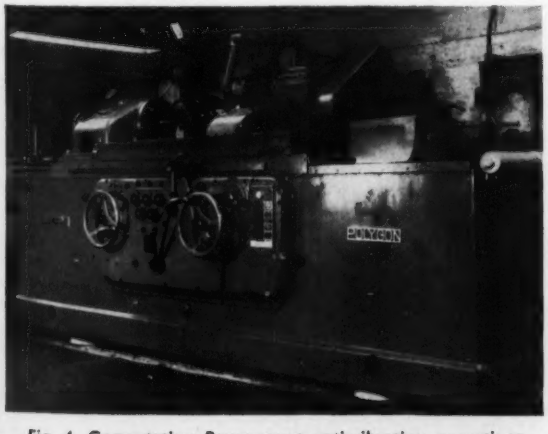


Fig. 4. Cementation Barrymount anti-vibration mountings fitted to a Polygon profile cylindrical grinder at the works of Andrew Fraser Ltd.

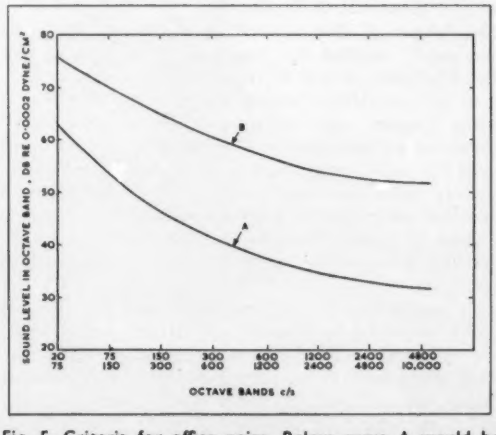


Fig. 5. Criteria for office noise. Below curve A would be a satisfactory background for conversation. Noise level above B would make use of telephone slightly difficult.

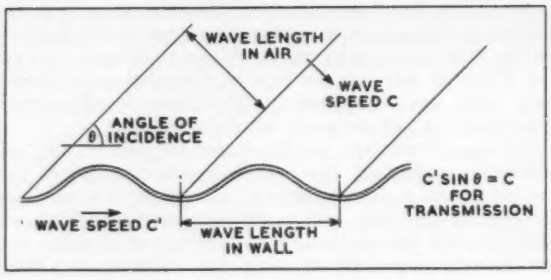


Fig. 6. Diagram of coincidence effect.

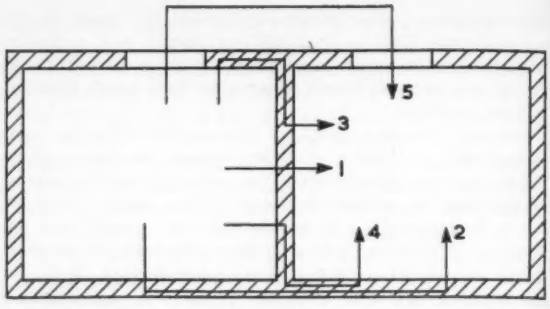


Fig. 7. Paths for sound transmission in a simple structure.

noisy gearwheels may be more accurately made, and so on.

This is, however, often impossible, and the next best way is enclosure. As pointed out earlier, this must be really solid (steel, brick, concrete, etc.) if high noise reductions are to be achieved. Tables for the TL of such structures are available.[4]

At this stage it is sometimes helpful to coat a machine with a casing of large panels, with a damping material similar to that used on car bodies. Several such materials are available, and are often worth while when sound is radiated from large areas.

Transmission of sound, in the form of vibration, frequently takes place along structures. Even enclosing a machine may not solve the problem completely, if the foundations are continuous. In such cases the use of anti-vibration mounts helps considerably. These are now available for machines weighing many tons, but expert advice should be sought in choosing them, as it is possible to make the problem worse by their incorrect use.

An example of an anti-vibration mounting used successfully is shown in Fig. 4.

If a noisy machine transmits sound through the floor into a room below, anti-vibration mounts may help in this case. Many floors (e.g., concrete) have a high TL for airborne sound, but transmit impact sounds, such as footfalls or hammer blows, readily. In such cases a false floor, such as a concrete slab "floating" on a glass fibre mat, or a floating ceiling below, will reduce the transmission of impact sounds considerably.

Transmission of sound through ducts, e.g., ventilating ducts, can be handled by lining the ducts with absorbing material. Techniques for this are well established.[5] In such cases where the fan produces a steady note, the author has used resonant absorbers, timed to the fan frequency, with success.

When all such measures have been taken, the use of acoustic absorbent material can be valuable; the reduction it gives is not great, but, if used in the room where silence is desired, it makes conditions rather more pleasant and also has an important psychological effect—a point by no means to be overlooked.

Much work is needed for a complete understanding of noise problems, but sufficient knowledge is even now available for many difficulties to be reduced.

REFERENCES
1. Beranek, L. L. "Criteria for Office Quieting", *J. Acous. Soc. Am.*, **28**, 833-52 (1956).
2. *Handbook of Acoustic Noise Control*, **2** (WADC. TR 52-204), U.S.A.
3. Mercer, D. M. A. "Industrial Deafness", *Safety at Work*, **1**, 103-11 (1957).
4. Beranek, L. L. *Acoustics*, McGraw Hill, 1954, Chap. 10.
5. Lemmerman, R. D. *Noise Control*, **3**, 28 (1957).

INCREASING FATIGUE RESISTANCE OF RIVETED JOINTS

ALTHOUGH the problem of fatigue and fail-safe techniques has been widely studied in aircraft engineering, such evaluations have their parallel in other fields such as nuclear engineering, where it is vital to avoid serious results in the event of failure.

The fatigue of riveted joints is a case in point, and a recent paper* showed that, from test data, bending stresses at the first rivet or row of rivets contributed roughly one-half of the total stress causing fatigue cracking. These high bending stresses can be reduced by thin doublers of titanium or stainless steel secured by an extra row of rivets outside the main splice. Such a joint showed a fatigue life of twenty times the life of a splice without such doublers. While this introduces a problem in bi-metallic corrosion, the gains in fatigue life and fail-safe features more than offset the precautions required for adequate corrosion prevention.

In a simple riveted lap joint, for example, the fatigue strength could be increased over 20 per cent by driving rivets through the ends of the overlapping plates. Corresponding increases in life were between five and ten times. The purpose of the edge rivets was to relieve the loaded rivets from bending stresses. A corollary to this would be to allow bending to take place at the first rivet, but to reduce the total stress at that position by means of a thin doubler extending beyond the splice so as to pick up an extra rivet or row of rivets through the doubler and skin only. The doubler would have to be thin enough to minimise bending stresses at the auxiliary rivets and yet strong enough to reduce the loads going into the main splice. In addition, this type of structure would lend itself to fail-safe design, provided the strength of the doubler alone were sufficient to carry the fail-safe load.

The tests, which were limited to one thickness of doubler, showed rather substantial gains in fatigue strength. Undoubtedly, still greater gains could be had by establishing optimum skin to doubler thickness ratios. It appears that added fatigue strength or weight saving can be achieved by using thin auxiliary doublers of high-strength material in an aluminium alloy structure. While the improvements shown by the tests were substantial, they are by no means optimum. An extrapolation would indicate that eventually a state in the art of designing fatigue-resistant structures will be reached where fatigue will not be a problem. The next step would be to approximate the fatigue strength of rivet-filled holes. Further improvement would probably depend on adhesive bonding in addition to the proper proportioning of doubler-to-skin thickness.

* Thin Doublers for Fatigue-resistant Aluminium Alloy Structures. Address by C. R. Smith, Convair division of General Dynamics Corp., at the 27th I.A.S. meeting in New York.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

Selsyn Drive System Eliminates Long Feed Shafts on Lathe

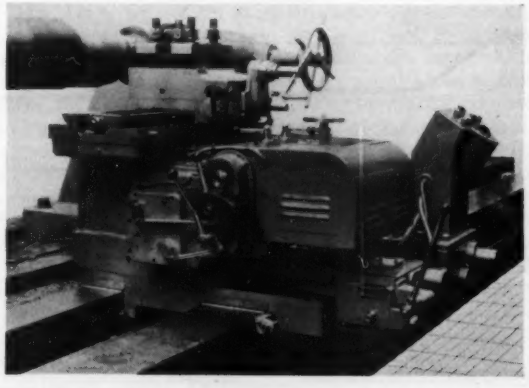
IN five large lathes, ordered by C. A. Parsons & Sons Ltd. from Craven Brothers (Manchester) Ltd., the smallest of which is illustrated, a number of considerable advantages have resulted from the replacement of long feed shafts at the front and rear of the bed. The evils of wind-up and distortion, always associated with long feed shafts, are eliminated, together with cumbersome tumbler bearings. It has also been possible to build a lathe with four shear ways within 9 in. of floor level, a feature of particular value when large workpieces must be loaded.

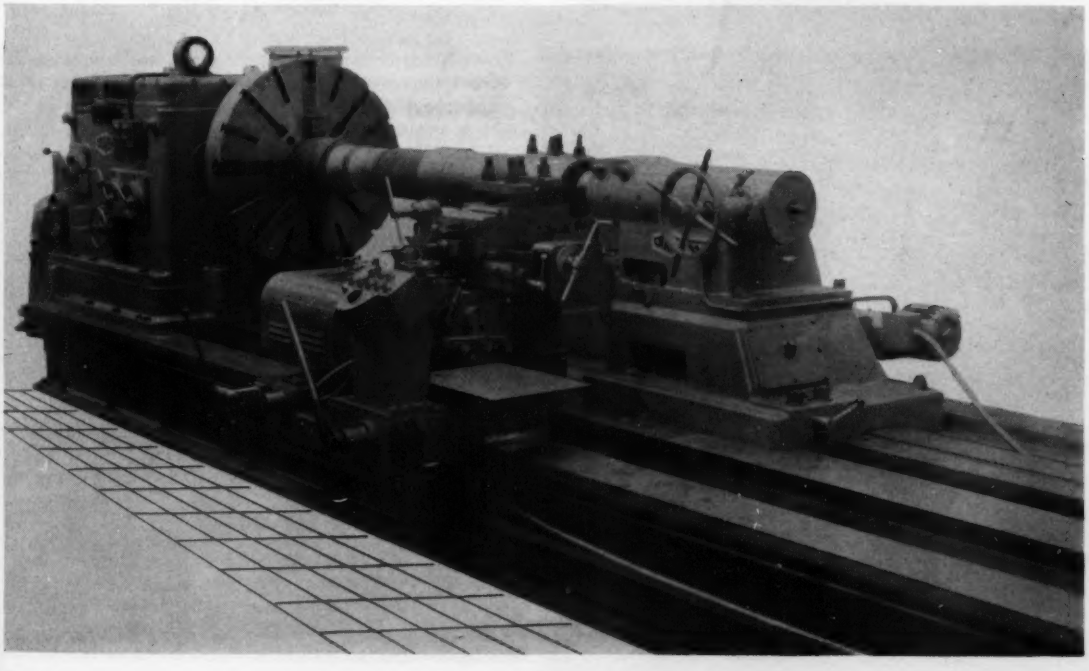
In a lathe with conventional saddle apron arrangement it would have been necessary to provide an open channel alongside the bed to accommodate the apron. In the two saddles of this new type of lathe, Selsyn motors are fitted which provide power feed along the bed by rack and pinion, transverse surfacing feed being by screw and nut. Power feed is also provided for the tool slide upon the top slide. A swivel slide on the front rest is of extra length to give a traverse of 24 in. for screw-cutting purposes.

Screw-cutting drive, from the receiver motor on the front saddle to the tool slide traverse screw in the swivel slide, follows the normal feed transmission through the feed gearbox and intermediate slide, but by-passes the feed drop worm engage gearing and safety slipping clutch, in order to ensure a positive screw-cutting relationship. Selection for cutting from two to twenty screw threads per inch is made by the use of certain gear changes in the feed box, in conjunction with appropriate change wheels mounted on the swing frame at the end of the swivel slide.

The two Selsyn receiving motors obtain their electrical supply from a transmitter generator driven by one of the shafts directly geared to the headstock spindle. Variations in workpiece rotation are thus immediately reflected in the output of the transmitter and so have a corresponding effect upon the speed of the receiver motor on the saddle, regardless of any change that may be made in work speed.

Tests carried out with the Selsyn drive on each of the machines show that the total error measured over a span of ten 0·5-in. pitch threads did not exceed 0·0012 in., while finer threads of 10 t.p.i. were cut to conform with normal standard thread gauges.



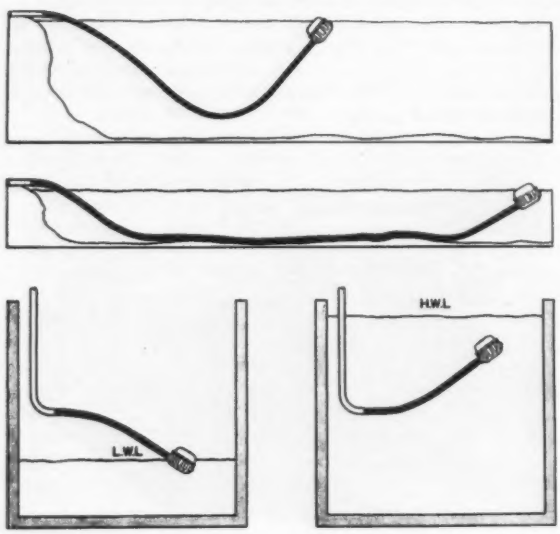


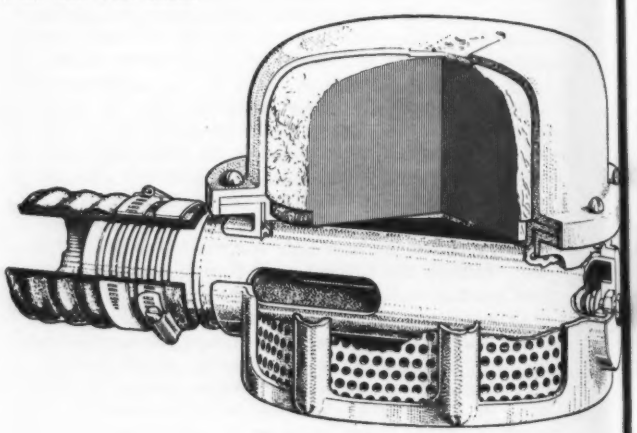
Floating Suction Strainer uses New Plastics

THE problem of drawing water from just below the surface of ponds, sumps and streams, thus avoiding the intake of both floating matter on the surface and sand or silt on the bottom, is claimed to have been solved by Megator Pumps & Compressors Ltd. with their Dolphin floating suction strainer. In addition, the possibility of vortex formation, which can put a centrifugal pump out of action, is avoided, as well as cavitation erosion which can occur when a strainer, working on the bottom of a sump, becomes blocked.

An impact-resistant and resilient plastics material is used for the main casework of the strainer, which can withstand very rough handling and abrasion. Within the upper part is a moulding of polystyrene foam, in which the many separate watertight air cells provide the necessary buoyancy to float the strainer. The lower, massively-ribbed part contains a perforated strip of plastics material, bent and joined to form the strainer. A moulded plastics tube, to which the hose is attached by two clips, allows the strainer to take up the correct floating position independent of any twisting tendency of the hose. As all the inlet holes are in the sides, there is no tendency for the strainer to be sucked downwards into the sand or silt, where it may eventually rest when working in "snore" conditions. The strainer is readily removed from the plastics tube by undoing one nut which, like all other metal parts in the strainer, is of austenitic stainless steel.

Four sizes of the strainer are available, for 1½-in., 2-in., 3-in. and 4-in. hoses.



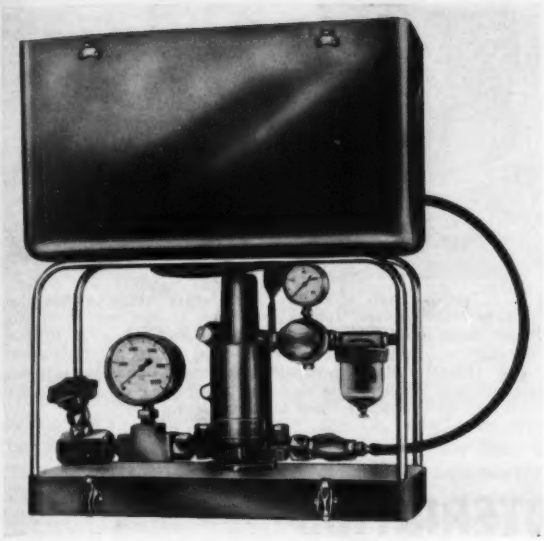


Self-energising Hydraulically-operated Concrete Bucket

THE Blaw-Knox hydraulic bucket does not require hydraulic or air-line connection at the point of placing the concrete. It is carried by two non-rotating multi-strand wire ropes, fitted to a spreader beam suspended from the crane or cable-way hook. Each rope is attached to the piston rod of a hydraulic accumulator ram and, as the bucket is hoisted, its weight, combined with the weight of the concrete load, generates hydraulic pressure within the accumulators to feed a four-way valve which controls the opening and closing of the gate. This valve is spring-loaded and is controlled by a short length of rope or light chain. Pulling the cord actuates the valve which directs hydraulic pressure to the gate-operating rams. Releasing the cord allows the spring return to move the operating valve, which then directs pressure to the other ends of the gate-operating cylinders, thus forcing back the pistons and closing the gate. Sufficient hydraulic pressure can be stored in the accumulators for two complete cycles of operation.

To recharge the accumulators it is necessary only to set the bucket down and pick it up again.

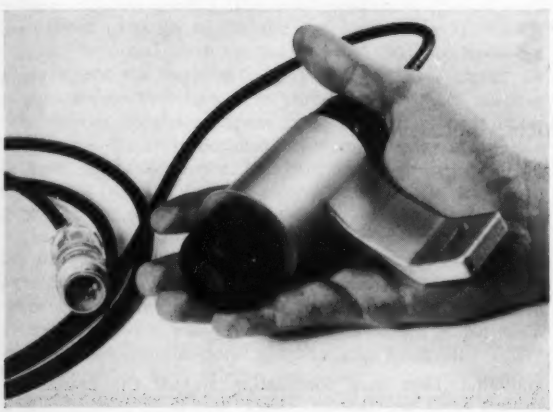
The same energy storage principle might well be employed in other fields, e.g. for opening lift doors.



Portable Hydraulic Test Set Maintains Pressure without Air Consumption

THE Madan hydraulic test set has been designed for carrying out pressure tests on site. The set only needs connecting to a compressed air line or, where this is not available, to a nitrogen or compressed-air bottle.

The pump works on the principle that the air pressure supplied to a large air piston imparts thrust to a hydraulic ram of smaller area, and so creates a high hydraulic pressure. This regulating action gives a continuous flow. The air pressure regulator control valve incorporated enables all the intermediate hydraulic pressures within the range of the pump to be accurately determined, and the manufacturers state that it is safe to leave the item undergoing test as the test pressure is never exceeded. The case, which is of moulded glass fibre reinforced plastics, serves also as a hydraulic reservoir when the set is in use.



Optical Transducer for High-speed Measurements

THE TL-2, an optical transducer having no moving parts, has been introduced in the U.S.A. by Southwestern Industrial Electronics Co. The instrument, which contains a photo-transistor, a light source and a lens system detects, by optical reflection, graduated lines placed on the moving surface of which the rotational or linear speed is to be measured, and is used in conjunction with an electronic tachometer. Mylar film with lines printed on it and with a pressure-sensitive adhesive backing is supplied for application to shafts, couplings or surfaces, thus eliminating shaft loading. The manufacturers claim that the instrument is virtually insensitive to vibration over a wide frequency and amplitude range. It can be used for speed measurements exceeding 1,000,000 r.p.m.

Radial Router with Three-Dimensional Copy Equipment

THE incorporation of copying equipment in the Wadkin heavy-duty router has produced a machine stated to be capable of performing work that, until now, has been only possible at a much slower rate on die sinking and copying machines.

The template to be copied is held overhead on a tee-slotted plate supported by substantial vertical columns. The router head carries a special slide which incorporates a hydraulic cylinder. This cylinder is actuated by an overhead stylus having a vertical adjustment of 3 in., which contacts the model or template to be copied and imparts an inverse movement to the head. The router head, carried on a rigid arm having an effective radius of 73 in. maximum and 33 in. minimum, moves on ball-bearing rollers housed in a carriage that is mounted on a barrel in the main frame. The barrel is mounted in pre-loaded taper roller bearings. A powerful lock is fitted to the arm to permit sweeps to be made with the arm locked at any required position. A similar pneumatic lock to the rotating movement on the barrel can also be provided. The locks are actuated from a lever on the operating handle of the machine so that the operator has instant control of all movements.

The work table, which may be fixed or provided with a power-operated rise-and-fall movement, measures 84 in. by 36 in. The maximum depth of component that can be worked is 16 in. and the maximum depth of contour, 6 in.

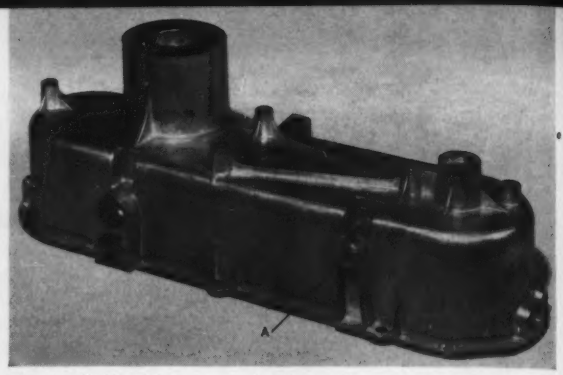


Fig. 1 (*Left*). High strength of zinc-base alloys makes them suitable for structural applications such as this textile machine frame. Cast in Mazak III, it weighs 14 lb. and is 25 in. long.

Fig. 2 (*Above*). Washing machine gearcase designed for maximum strength and rigidity. The zinc-base alloy remains unimpaired by humidity and alkaline detergents.

ECONOMICS AND CHARACTERISTICS OF DIECAST COMPONENTS

In the production of certain components and products, diecasting can offer a number of advantages for economy and simplicity. This article explains how best results can be obtained with the process

by **H. K. BARTON**

AS a metal-working technique, diecasting combines the ease, speed and economy of the foundry processes with a level of dimensional precision fully comparable with close-limit machining operations. Diecastings come from the die, in many instances, as finished products that require only trimming in a press to remove the feed-metal, or "sprue", before they are packed for dispatch. By contrast, other diecast components, such as binocular and camera casings, undergo elaborate sequences of machining and finishing operations, yet show impressive economies compared with any other manufacturing method.

The industries taking greatest advantage of the varied merits of the diecasting process are, for the most part, those concerned with the quantity production of durable consumer goods: cars, domestic equipment and office appliances. In many applications, such as photographic equipment, communications equipment and electronic devices, the use of diecastings is fundamental to economic production, even though on a tonnage basis the consumption of diecasting alloys is not large.

DIECASTABLE ALLOYS—Virtually all non-ferrous metals with a melting point below 1,000 deg. C. can be diecast, but in practice only a limited number of specialised alloys, which experience has shown to be particularly well suited to the process, are diecast commercially. The most important are the two zinc-base alloys to B.S. 1004 (see Table 2) and the three aluminium alloys shown in Table 3. Alloys of lead and tin are also diecast, the former finding a small but increasing use as shielding elements for film cassettes and other items needing protection from radioactivity.

Of the copper-base alloys, 60/40 brass can be readily diecast, though not to such close limits as the light metals and zinc. Dies used for casting any of the brasses are subject to severe thermal shock and their effective life is short; in the main fields for brass diecastings the competition from hot brass pressings is severe. When the present position of copper-base diecasting practice is viewed against the tremendous advances made in both zinc and light-alloy diecasting during the post-war years, it is clear that, unless radically new techniques appear, the high-melting-point alloys are destined to play a decreasing part in total diecasting production.

Essentially, the diecasting process is the simplest of foundry techniques, for it makes no use of expendable materials for mould, core or pattern, as do other processes. A diecasting machine in operation is a complete and self-contained production unit; molten alloy is converted in a single step into a finished or semi-finished article. Because all the sources of variation associated with expendable mould materials are eliminated, the successive castings produced from a diecasting die are dimensionally invariant to a high degree.

A diecasting die consists of two or more abutting steel blocks, clamped in intimate contact between the platens of the diecasting machine; the surfaces in contact are termed the "joint faces" of the die. A negative impression of the component to be produced is formed between the joint faces of the blocks and, in the simplest case, a die consists of a pair of rectangular blocks.

Each cavity connects with an orifice in the die (the sprue-hole) through which molten metal is injected under pressure. As the metal enters, air escapes along the joint faces of the die and by way of vents provided for the purpose. The metal fills out the cavity completely in a fraction of a second and, in contact with the cool die

surface, solidifies almost instantly. As soon as solidification is complete, the die is opened and an array of sliding ejector pins pushes the diecasting clear of the cavity. The speed of this operation is roughly proportional to the weight of the component produced, and in practice varies from 700-800 cycles per hour for diecastings weighing approx. one ounce to as few as 40-50 cycles per hour in the case of components weighing 15-20 lb. Factors tending to reduce production speed are: (1) intricacy of form, demanding a mechanically complex die; (2) variation in section thickness, with the consequent delay in solidification of the thicker parts; (3) the presence of "inserts" requiring to be located in the die at each casting cycle and (a point of considerable importance) the closeness of limits that must be held on critical dimensions between two relatively moving elements of the tool.

Characteristics tending towards fast and economical production are the reverse of the above, i.e., thin, even sections free from local increases (heavy bosses rising from a thin web, for example) or abrupt changes of contour, the elimination of features calling for a complex die or an interrupted casting cycle, and the establishment of dimensional limits at a level consistent with the normal levels of process control. The tolerances to be applied vary from point to point within the die[1] (see Table 1).

It will be noted from the values cited that the zinc-base alloys afford the highest dimensional accuracy under all circumstances. This is due in part to their lower melting point, which does not impose large thermal stresses upon the die, but is mainly because lower injection pressures can be used. In consequence, the hydrostatic pressure within the molten metal filling the cavity exerts less thrust to displace the movable die elements.

The zinc-base alloys are not only the easiest to diecast, but are also stronger than the light alloys for equal cross-sectional areas. Additionally, zinc-base alloys lend themselves admirably to electroplated finishes, as evidenced by the very wide use of zinc alloy diecastings for such items as automobile door handles and boot hinges. On the other hand, it is seldom necessary to use an applied finish on zinc-base components merely for protective purposes; they do not rust and, although on open exposure they gradually acquire a greyish coating, the rate of corrosion is low even in heavily polluted industrial atmospheres.

The light alloys, although not so strong as the B.S. 1004 zinc alloys section for section, have a superior strength-to-weight ratio. Moreover, since their weight per unit volume is much less, it frequently happens that the metal cost for identical castings in zinc and aluminium would show the latter to be cheaper. In practice such a crude comparison tends to be misleading, for very seldom do two diecastings with the same functional requirements prove to be identical in every respect if designed specifically for each of the two alloy groups.

Broadly, the position is that aluminium diecastings are generally of thicker wall section than comparable zinc diecastings, partly in order to provide adequate structural strength and partly for ease of production. Instead, therefore, of an aluminium diecasting weighing only two-fifths as much as the same article in zinc (as a comparison of the specific gravities leads one to expect), the weight frequently is between one-half and three-fifths that of a zinc diecasting performing the same function.

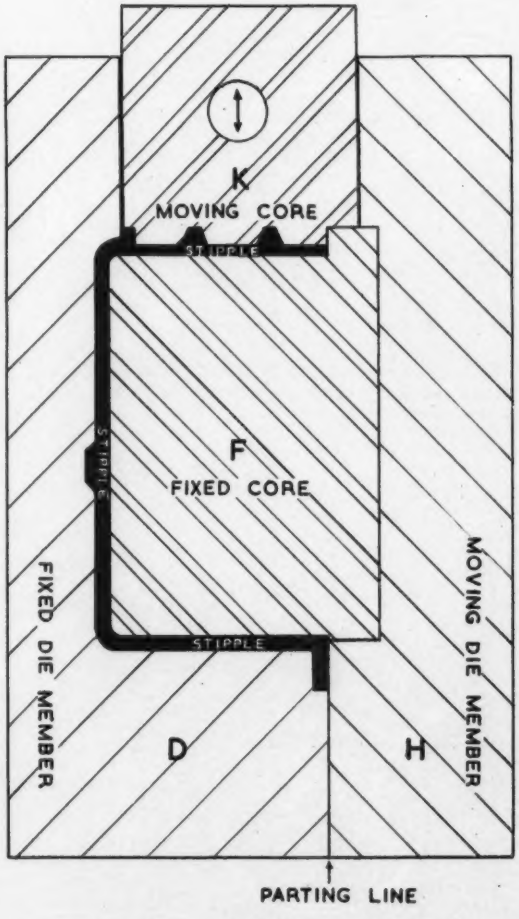
Applications of Light Alloy Diecastings

Even with this reservation, the high strength-to-weight ratio of aluminium diecastings renders them of particular value in many applications where dimensional accuracy and structural strength need to be coupled with low inertia. To take one outstanding example, the economic production of aluminium alloy torque converters, and other automobile transmission elements, could hardly have

TABLE 1. Tolerances on diecastings (for use in conjunction with the drawing below).

Type of Dimension	Alloy Group		
	Zinc	Aluminium	Magnesium
Linear Tolerance: Between two fixed points in any one of blocks H, D, F or K.			
Basic tolerance for first inch	±0·002	±0·003	±0·003
Each additional inch	±0·001	±0·0015	±0·0015
Between one point in H and one in D or F, add to linear tolerance for casting area up to			
25 sq. in.	±0·003	±0·004	±0·004
25– 50 ,, ,,	±0·004	±0·005	±0·005
50–100 ,, ,,	±0·006	±0·008	±0·008
100–200 ,, ,,	±0·008	±0·012	±0·012
200–300* ,, ,,	±0·012	±0·015	±0·015
Between a point in moving core K and one in either F or H, add to linear tolerance, according to area of casting formed by K.			
Up to 10 sq. in.	±0·004	±0·005	±0·005
10–20 ,, ,,	±0·006	±0·008	±0·008
20–50 ,, ,,	±0·008	±0·012	±0·012
50–100* ,, ,,	±0·012	±0·015	±0·015

* Where larger areas are in question, determine tolerances in consultation with diecaster.



Cross-section of die to show tolerance limits in Table 1 above.

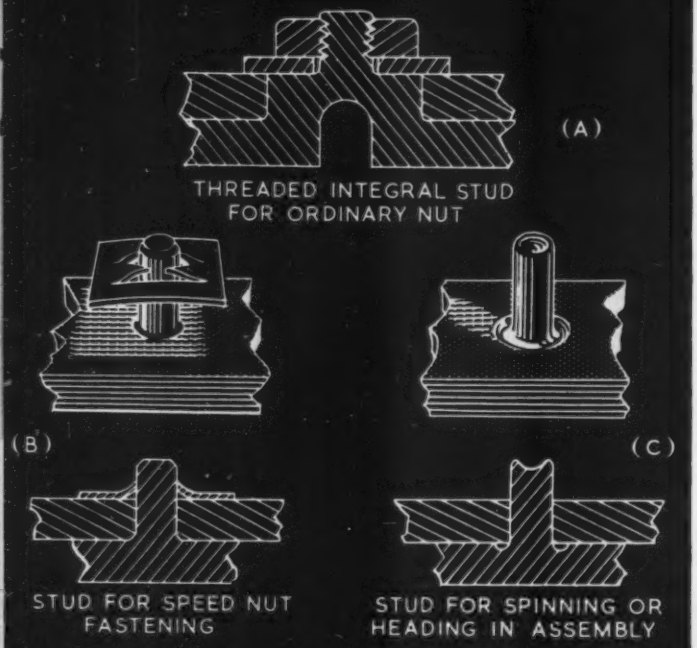


Fig. 3. Integral studs on diecastings may be subsequently threaded (a), but threaded inserts are usually preferable. Other common fixings are spring fixes (b) and riveted or spun studs (c).

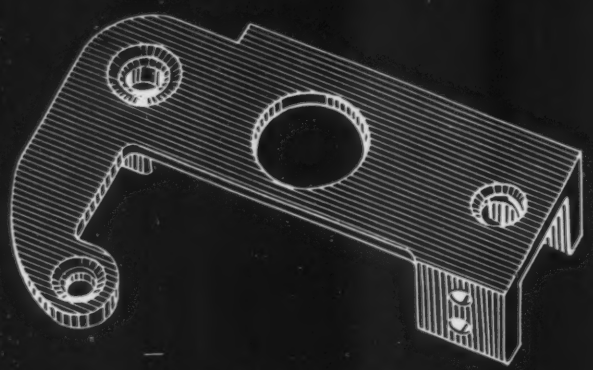


Fig. 4. The sheet metal dial bridge piece on the Stromberg-Carlson telephone was originally blanked and pierced, formed, drilled, reamed, drilled again and then tapped (six operations). The diecasting which replaces it, at less than half the cost, requires drilling and tapping only.

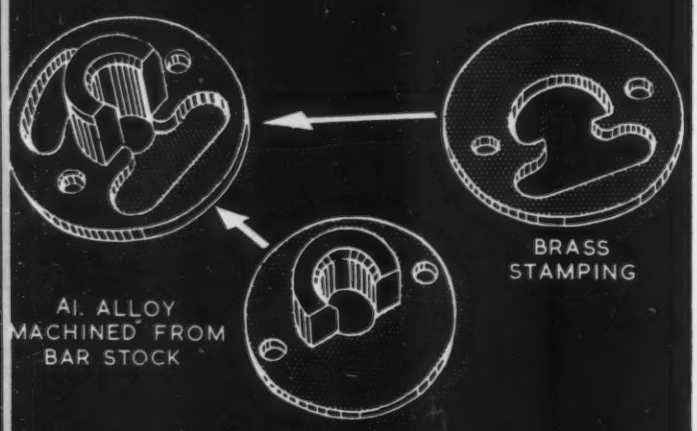


Fig. 5. Turned from bar stock, the metal wastage on the part in the foreground was over 60 per cent. Wastage on the diecasting (left) is negligible.

been achieved other than by diecasting. Magnesium alloys have an even more favourable strength/weight ratio, and are particularly well suited to diecasting production, but they oxidise so rapidly when molten that special equipment has to be used and it is consequently difficult to carry on the diecasting of magnesium alongside other alloys. Few commercial diecasters therefore consider it worth while to offer castings in these alloys, even though the price differential between Mg and Al alloys, on a volume basis, often favours the former. Most magnesium diecastings are produced by a small number of companies having specialised handling facilities.

The diecasting of copper-base alloys on an economic basis has for long been a prime aim of the world diecasting industry, but it is still only in a few restricted fields that brass diecastings can compete, and then for the most part marginally, with castings produced by other "precision" processes. Hot brass pressings, extrusions and other techniques producing semi-finished pieces are also competitive. The main difficulty to be overcome is the short die life; high thermal stresses at metal injection cause rapid breaking up of the die-surface. Indeed, it seems probable at present that the diecasting of ferrous alloys will become commercially practicable before diecast brass achieves any real importance. Both merits and shortcomings of the diecasting process are indicated in the comparison chart of Table 4.

The major advantages of diecastings over metal components produced by other volume production methods are:

1. The exceptional dimensional accuracy, sharpness and planarity which can only otherwise be matched on fully-machined parts.

2. The extreme complexity of form which is achievable; this makes possible the production as a single integral diecasting of functioning parts previously built up from a number of separate components.

3. The variety of surface treatment that is possible; diecastings may be smoothly contoured for ease in polishing and plating, ribbed, finned, stippled or "engine-turned", or produced with integral nameplates, insignia, circuit diagrams or instructional panels.

4. The "as-cast" finish of diecastings is frequently quite adequate for primarily "functional" parts which, though visible in service, do not have to be decorative. If parts of poorer intrinsic finish, such as sand-castings, are used in such applications, it is necessary to improve the surface (usually by spraying an organic finish) to mask the superficial imperfections.

THE QUALITIES OF DIECASTINGS—Complexity, rugged strength and high dimensional accuracy are all manifest in the diecast frame for a textile machine seen in Fig. 1. This component exhibits many of the useful features that can be incorporated in diecastings. The face of the wall, A, is cast flat for assembly of a mating part without machining, and cored holes for tapping are formed in buttresses such as those at B, integral with the wall. At C is a threaded steel insert, cast in place; this provides added strength and avoids a threading operation on a slender stud. Such inserts as these are often of considerable value in improving the local mechanical properties of a component and at the same time avoiding a secondary operation. Among the commonest types of insert, after the threaded stud, are bearing bushes of brass, steel or even of nylon and threaded bushes used in preference to the subsequent tapping of a cored hole.

The washing-machine gear housing in Fig. 2 demonstrates the use that can be made of ribs and buttresses to add strength to a component subject to high stresses in service. Of particular interest is the construction adopted for the shaft-housing at A, with its two stiffening ribs carried down to the base. To produce the pocket thus

TABLE 2. Composition and properties of zinc-base diecasting alloys

		B.S. 1004: 1955	
		Alloy A	Alloy B
Composition, %:	aluminium	3·8 to 4·3	3·8 to 4·3
	copper	0 to 0·10	0·75 to 1·25
	magnesium	0·03 to 0·06	0·03 to 0·06
	zinc	remainder	remainder
Max. impurities, %:	iron	0·10	0·10
	lead	0·005	0·005
	cadmium	0·005	0·005
	tin	0·002	0·002
	thallium	0·001	0·001
	indium	0·0005	0·0005
Impact strength in ft./lb.		42	43
Elongation, %		15	9
Tensile strength, t.s.i.		19	22
Brinell hardness		83	92
Density		6·6	6·7
Solidification range, °C.		380–386	380–386
Solidification shrinkage, in./ft.		0·14	0·14
Coefficient of expansion		27×10^{-6}	27×10^{-6}

Figures for composition and max. impurities refer to cast parts; limits on ingot metal are more rigorous

TABLE 3. Composition and properties of aluminium casting alloys mainly used for pressure diecastings

		B.S. 1490: 1955		
		LM 2	LM 4	LM 6
*Composition %:	copper	0·7 2·5	2·0–4·0	0·1
	magnesium	0·3	0·15	0·1
	silicon	9·0 11·5	4·0–6·0	10·0 13·0
	iron	1·0	0·8	0·6
	manganese	0·5	0·3–0·7	0·5
	nickel	1·0	0·3	0·1
	zinc	1·2	0·4	0·1
	lead	0·3	0·1	0·1
	tin	0·2	0·05	0·05
	titanium	0·2	0·2	—
	others	—	Fe + Mn 1·3	—
0·1% proof stress, t.s.i.‡	—sand	4·5	5·0	3·5
	—chill	5·0	5·0	4·5
Tensile strength, t.s.i.†	—sand	8·0	9·0	10·5
	—chill	9·5	10·0	12·0
Elongation on 2 in., %†	—sand	—	2	5
	—chill	—	2	7
Specific gravity		2·70	2·75	2·65
Weight/in.³ (lb.)		0·097	0·099	0·096
Freezing range, °C.		525–570	525–625	565–575
Corrosion resistance		G	G	E
Machinability		F	G	G
Casting characteristics	—sand	G	G	G
	—gravity	G	G	E
	—pressure	G	G	G

E—Excellent. G—Good. F—Fair.
* Single figures are max. contents. † Specified test bar requirements.
‡ Min. expected values.

formed it is necessary to use a sliding core-block, so that such features are seldom economic unless the sliding block can also be used for a functional cored hole. This is the case with the gear housing. A similar sliding block is required to form the two holes at lower left; here again a recess in the component above the cored hole reduces what would otherwise (Fig. 6) be an unduly heavy section.

The control body of Fig. 7, with its side covers, is a good example of a set of diecastings designed for the easy location of internal sub-assemblies. The thin walls and slender bosses, the latter cored for attachment of the side-plates, provide adequate strength with minimum weight. Also of interest are the thin circular inner wall joined to the case by a rib and also the locally thickened section with its cored buttress immediately above. This component is an outstanding example of a strictly functional design which takes fullest advantage of the diecasting process.

All the diecastings illustrated are in the medium-large size range. However, the process is well adapted to the production of components weighing as little as an ounce, and in fact many millions of diecastings weighing a fraction of this are produced every week. The majority of parts in the smaller ranges are of zinc-base alloy. Almost all of the standard finishing treatments can be successfully applied to diecast articles. Those most often employed are painting and lacquering, electroplating and buffing the natural surface to a high lustre; in a recent survey, these were the finishes adopted on approximately 40, 30 and 20 per cent respectively of diecastings produced. However, the picture is only complete when it is pointed out that, where-as both zinc and light-alloy diecastings receive organic finishes in about the same proportions, it is the aluminium castings which are polished and, almost exclusively, the zinc-base components which are electroplated.

CONVERSIONS TO DIECASTING—The majority of conversions to diecasting are from other foundry processes, and it is seldom that the diecasting is as cheap as the raw casting previously bought in. The savings arise out of reduced machining, where they are often spectacular, and greater ease of finishing. For some components, diecasting offers the only possible means of achieving the quality standards required on a volume production basis. An example of this is a pair of variable ratio gears used in an office machine; to machine the prototype pair cost well over £100 (about as much, in fact, as it subsequently cost to sink the cavities in the diecasting die) whereas the cost of the diecast gears, virtually identical in accuracy and possibly superior in running qualities, was only a few

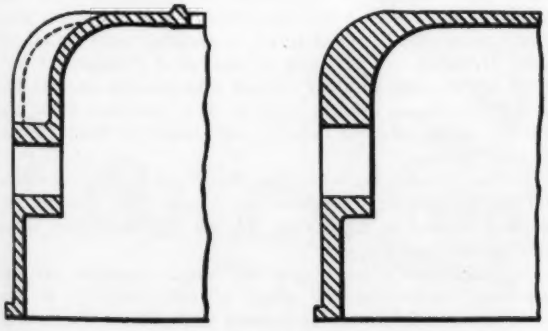
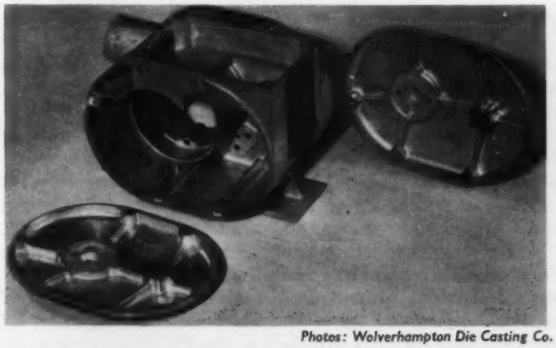


Fig. 6. Recesses in the outside face of this gearcase above lateral cored bosses avoid heavy sections (as shown in the right-hand illustration).



Photos: Wolverhampton Die Casting Co.

Fig. 7. Thin walls and intricately-cored recesses characterise this zinc-alloy control body.

TABLE 4. Comparison of design factors and costs for various production processes

Low numbers indicate most favourable process	*Large stamping or pressing*	*Light alloy die-casting*	*Al. permanent mould casting*	*Zinc-base die-casting*	*Injection moulding*	*Small stamping or pressing*	*Compression moulding*	*Hot pressing*	*Impact extrusion*	*Sintering*	*Turned bar stock*	*Plaster-mould casting*	*Shell-mould casting*	*Sand casting*
Adaptability to product styling	2	1	3	1	1	2	1	4	*	*	8	5	6	7
Size range	*	1	2	1	3	*	3	4	6	6	*	5	4	1
Minimum size	*	2	5	1	4	2	5	5	4	3	3	4	5	5
Maximum size	1	2	1	2	4	*	3	8	9	7	7	8	2	1
Dimensional accuracy	2	2	4	1	2	1	1	3	2	1	2	4	5	6
Natural finish	5	4	6	3	2	5	1	6	2	*	5	6	7	8
Scope for applied finishes	2	1	2	1	*	2	*	3	*	*	3	3	4	4
Possible thinness of section	2	3	2	1	3	1	3	4	1	3	*	4	5	6
Possible thickness of section	7	5	3	4	5	8	6	2	9	2	*	2	1	1
Ease of incorporating inserts of other materials	*	4	4	3	2	*	1	*	*	*	*	5	5	5
Possible complexity of form, external	4	2	4	1	3	4	3	4	6	5	4	1	3	3
Possible complexity of form, internal	4	2	3	3	3	4	3	4	5	5	6	1	1	1
Initial tool cost	14	13	12	11	10	9	8	7	6	5	4	3	2	1
Tool maintenance cost	12	11	10	8	7	9	8	5	5	4	6	3	1	2
Machining cost	2	3	2	2	2	1	2	5	2	1	8	4	6	7
Finishing cost	5	2	4	1	‡	‡	‡	3	‡	‡	5	4	6	7
Assembly cost	4	1	4	1	†	2	2	2	†	1	3	4	5	6

* No data, or inapplicable. † Seldom form part of assemblies. ‡ Generally used without applied finish.

shillings. Even on conversions of simple stampings, however, savings are often appreciable; converting the telephone dial bridge of Fig. 4 from a punched and formed brass sheet to a zinc diecasting reduced the cost by 63 per cent. Savings of this order are by no means unusual, particularly where metal wastage is high. The one-piece diecast aluminum wheel bushing shown in Fig. 5 was originally produced by assembling two elements, one turned from bar stock and milled away on the hub, the other punched from sheet. The two parts had to be riveted together. When the diecasting replaced this assembly, the actual saving in manufacturing cost was 76 per cent. Additionally, however, the die was constructed in such a way that it was possible to produce either of two patterns of wheel bushing, differing only in hub length, from the one tool. The tolerances held on the diecasting are within the limits originally set for the machined part.

REFERENCE
1. "Engineering Standards for Pressure Diecastings", Zinc Alloy Diecasters Association.

EFFECT OF SHOT-PEENING ON FATIGUE STRENGTH

DURING past years a large amount of experimental data has been published indicating the beneficial effects of shot-peening on the fatigue strength of both laboratory specimens and manufactured parts.

The increase in the fatigue limit of polished laboratory specimens due to shot-peening varies from 2-14 per cent. In contrast, the improvement of manufactured parts is variously reported from 18-46 per cent.

Shot-peening increased the fatigue strength of the as-received or roughened surface 19-32 per cent and polishing increased it 19-26 per cent. The conclusion is that either polishing or shot-peening a roughened or as-received surface gives a substantial improvement in fatigue strength, with the shot-peening only slightly more beneficial than polishing.

As an example, the fatigue limit of an as-forged car axle was increased by shot-peening by 46 per cent and a steering knuckle showed a 28 per cent increase, as determined by rotating bending fatigue machines. The principal factors contributing to the decreased fatigue strength for the as-forged parts were said to be surface decarburisation and roughness.

At least three effects are introduced by shot-peening, i.e., cold working, residual stress, and stress concentrations.

COLD-WORKING—The beneficial effect of cold-working on fatigue strength has been established by several investigators. The fatigue limit for bars stretched between the yield point and the ultimate strength was increased 25 per cent, and for bars stretched to the ultimate strength, 46 per cent.

It has been observed that the surface flows more easily than the interior, causing a definite measurable hardness gradient across the diameter, and it can be shown that there should be a residual-stress pattern associated with such a hardness pattern that is characterised by favourable surface compression.

Certain makers believe that 80 per cent of the increase in fatigue strength was due to residual stress, and the remainder to cold-working or a physical change in the surface of the material.

RESIDUAL STRESS—Although greater emphasis has recently been given to the effect of residual stress on fatigue strength, probably the earliest, and still the most comprehensive, investigation was made by Buhler and Buchholtz. The residual stresses were introduced into carbon steels by quenching from the tempering temperature and, when measured by mechanical dissection, were found to vary from 40-100 per cent of the yield strength. It has been shown that residual surface compressive stresses increase the fatigue limit an average of 13 per cent. Residual surface tensile stresses, however, decreased the fatigue limit 14 per cent.

STRESS CONCENTRATION—The detrimental effect of stress raisers on fatigue strength is well known, but there is no known method of measuring this for the roughness of a shot-peened surface.

Investigations indicate that the fatigue strength can be predicted, neglecting the effect of cold-working, if the residual stress is treated as a mean stress and if the fading of residual stress is taken into account.

Summary of a paper presented by R. P. Felgar to a recent A.S.M.E. meeting in the U.S.A.

SELECTION OF PNEUMATIC ACTUATORS

For the designer faced with the need for specifying an air-powered jack or ram, this article discusses the characteristics of the many types available and will assist him in narrowing his field of choice

by J. A. COATES*

COMPRESSED air, being one of the most convenient and simplest forms of power available, is finding increased application and popularity in industry today.

Pneumatic tools, such as drills, screwdrivers, presses, hammers, chucks, riveters and many others, are used extensively as a means of increasing production and reducing manual fatigue.

In road transport, the size and weight of modern vehicles have necessitated a means of overcoming the human effort required for their safe control and, to this end, pneumatic braking and power-assisted steering, on the heavier class of vehicles in particular, are playing their part.

In the machine tool industry, compressed air is finding increasing favour as a means of providing an inexpensive means of power transmission.

A relatively new field of application is in the aircraft industry, where compressed air is used for operations such as undercarriage retraction, flap actuation, fuel cock control, fuel jettison, emergency canopy release and thrust reversal systems. In the interests of space limitation and weight, pressures of up to 1,500 p.s.i. are currently being used and higher pressures are envisaged, a particular characteristic of pneumatic equipment in aircraft being that the stored energy in the form of high pressures represents very little weight.

In the advance towards higher flight speeds, aircraft designers are considering temperatures in the order of 550 deg C.; it is interesting to note that recent studies indicate the strong likelihood of stable pneumatic control in temperatures of this range, where other methods might prove unstable.

* *Design staff, Vickers-Armstrong (Aircraft) Ltd., Hurn.*

Fig. 1. Dunlop ram operating the thrust reversal system on a Rolls-Royce power plant.

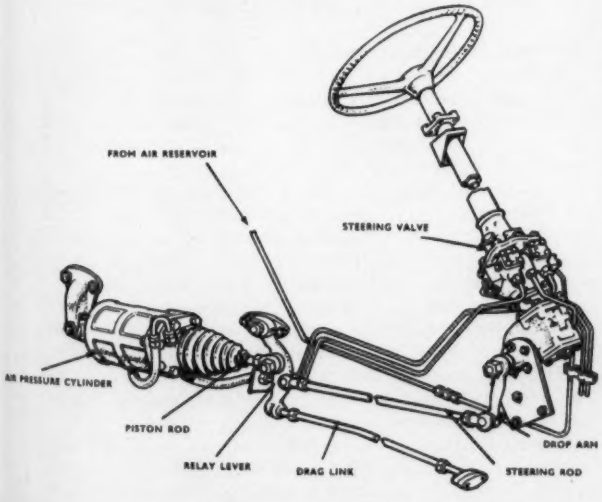


Fig. 2. Automobile power steering using Clayton Dewandre air pressure cylinder.

Of the many and varied pneumatic power devices, one of the most widely used is the linear actuator. It will be of value here to indicate the various types available to industry today, together with an introduction to simple air line layout and cylinder control.

Air Line Layout

The normal air line arrangement adopted in most factories is the ring main circuit (see Fig. 3), the greater volume of piping and alternative paths offered to the air tending to damp any fluctuations in the air supply line caused by sudden demands throughout the system.

Clean, dry air and good lubrication are the main essentials for efficient operation of a pneumatic actuator and the following features should be considered in the layout of the air supply lines:

1. Air intakes situated to provide the cleanest, driest and coolest air available.

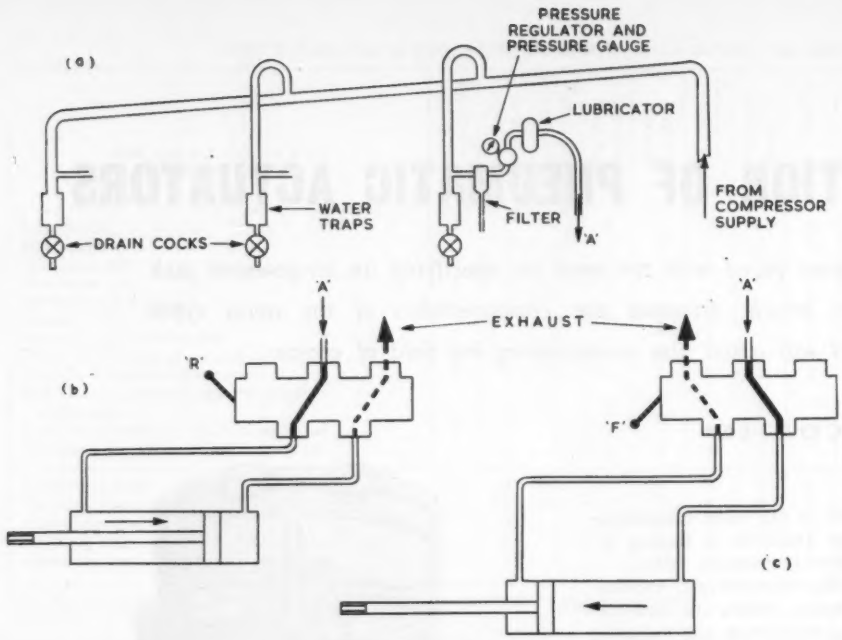
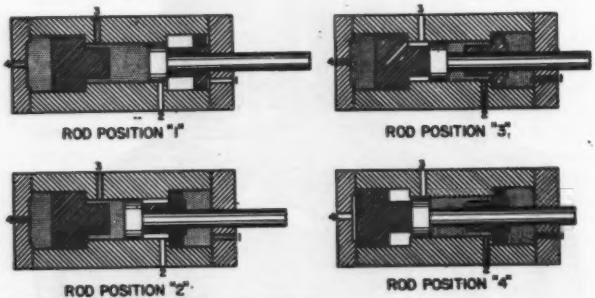


Fig. 3. Typical air line layouts. (a) shows a typical ring main layout. (b) and (c) represent control of a double-acting cylinder by a four-way lever-operated valve. At (b) the control lever is in position R, allowing air supply, A, to move piston rod to the rear position. In (c) the control lever is in the F position, passing air supply, A, to rear of cylinder and thrusting piston assembly forward.



Rod Position	Ports to Which Pressure is Supplied			
	1	2	3	4
1			X	X
2	X		X	X
3	X	X		X
4	X	X		

Fig. 4. Section through a Westinghouse four-position cylinder.

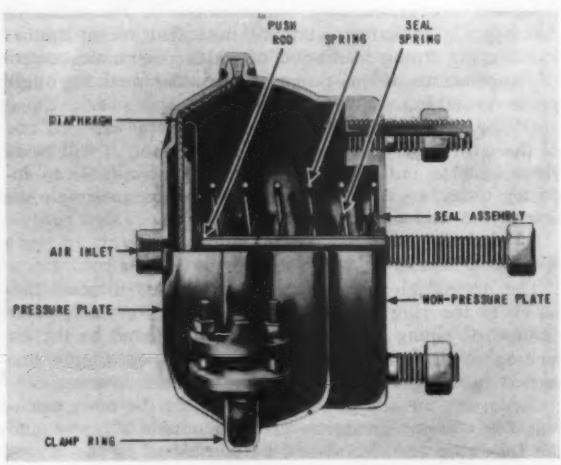


Fig. 5. Diaphragm-type brake cylinder by Bendix-Westinghouse and made under licence by Clayton Dewandre.

2. Main and branch lines to be large enough to avoid excessive pressure losses under maximum flow conditions.

3. Main lines, after rising from the compressor, slope gently away, so that any moisture present in the line is assisted to drainage outlets by gravity and airflow.

4. Branch lines to be taken from the top of the main lines and not from the bottom, to avoid unnecessary collection of moisture.

5. Filters placed as near the pneumatic actuators as possible and as low as possible.

6. Lubricators situated physically higher and downstream of filters.

7. To assist drainage, pressure regulators, when fitted, should be physically higher than filters and are generally fitted downstream from filters.

8. Gentle bends to avoid pressure drops.

Stop valves should be fitted to enable isolation of a particular section of the air line circuit.

Pressure gauges are usually fitted on the downstream side of pressure regulators. (Units are available combining filter, pressure regulator, pressure gauge and lubricator.)

Control of Actuators

PRESSURE CONTROL—Because of varying demands throughout an air line circuit, large fluctuations of pressure can be experienced; hence, to ensure a constant, controlled pressure on the approach to a particular application, air pressure regulators are fitted.

This item of equipment can either be adjusted to give the maximum constant pressure available (i.e., valve would be adjusted slightly below the anticipated minimum line pressure) or be set to, say 10 p.s.i. when required to clamp a fragile part. In another instance the return stroke of a cylinder may require a lower actuating pressure than the forward stroke. A pressure regulator properly adjusted on the return side of the cylinder will prevent unnecessary build-up of pressure and present a saving in overall air consumption. (Note: A pressure regulator does not control the speed of air flow.)

SPEED CONTROL—Unless restricted, air cylinders can operate at very high speeds and the speed control of a cylinder is usually effected by an air flow regulator which, by turning a knob can give precise control of cylinder speed from approaching zero to a maximum by restricting

the flow of air to or from the cylinder. The air flow regulator restricts flow in one direction only, allowing full-bore flow in the opposite direction.

With fast-moving cylinders it is usual to fit the air flow regulator to control the air entering the cylinder. For the more usual slower speeds, the control is applied to the air exhausting from the cylinder, thus allowing the piston to move against a constant back pressure and prevent uneven piston movement when working against uneven loads and back pressure.

As an alternative method of overcoming the effect of the compressibility of air, where cylinders are required to provide a constant rate of feed against varying loads, a form of hydraulic control may be used. This usually takes the form of a combined hydro-pneumatic system where the cylinder is actuated by hydraulic fluid pneumatically controlled. This class of actuator is not included in this particular survey.

CUSHIONING—When an actuator is required to operate at high speeds, a considerable amount of self-destructive energy can be imparted to the cylinder, the work piece and the surrounding structure at the end of the piston stroke, by virtue of the inertia of the moving parts.

This effect can be overcome by using the compressibility of air to retard the piston speed at the end of its stroke. Fig. 11 shows a cross-section through a double-acting cylinder with cushioning at both ends of stroke. The operation is as follows: towards the end of each stroke, the cushioning piston (1) enters the end cover cavity, so preventing further free exhaust of air via the main air connection, the exhaust rate being controlled during this part of the stroke by the cushioning control needle (3), which is adjustable.

OPERATOR CONTROL—Although there is little choice in the positioning of the actuating cylinder, since the cylinder must be mechanically connected to the working part, the location of the operating valve may be governed by convenience, depending on design requirements and whether hand or foot control is necessary. However, from a circuit efficiency standpoint, the control valve should be as near as possible to the actuating cylinder, advantages thus occurring being principally:

1. Reduction of time-lag between control valve operation and piston movement, since operating air has less distance to travel.
2. Economy of air, inlet pipes as well as cylinders being filled with air for each operation, any unnecessary pipe lengths are wasteful.
3. Less pressure drop, long pipe lengths increasing pressure drop, which can affect speed and cost of operation.
4. Possible use of smaller valves, since close coupling gives faster piston operation and less air wastage to maintain the normal operating speed of the working part required.
5. Saving in materials cost.

Types of Cylinders

On page 265 are shown the general arrangements of the piston-type cylinders in common use, together with the various mounting styles referred to in the tables.

SINGLE-ACTING (SPRING RETURN AND NON-SPRING RETURN)—In single-acting cylinders air is admitted to one side of the piston only, and exhaust is removed via breather holes at the opposite end of the cylinder. Used mainly for light duties, such as in jigs and fixtures and for ejection purposes, it is not suitable for use under arduous-duty conditions, as dirt, grit or moisture are liable to be drawn into the cylinder through the breather holes, causing rapid wear of the cylinder barrel and piston.

Spring-return types are limited in stroke and bore, both of which are governed by the spring. When non-spring types can be utilised, i.e., when the return stroke of the

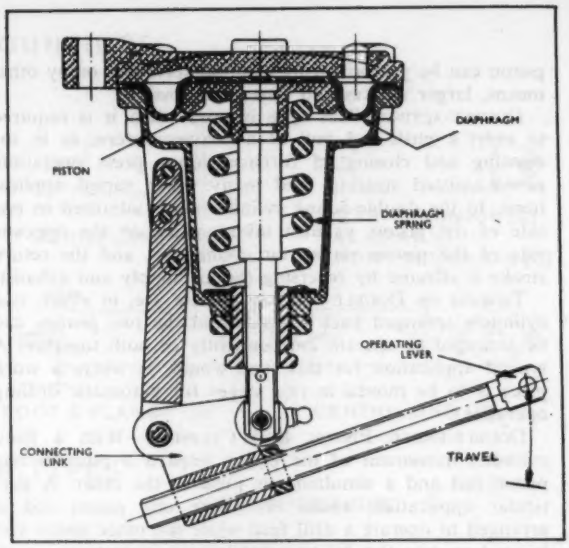


Fig. 6. Positional actuator with section showing internal mechanism (Westinghouse).

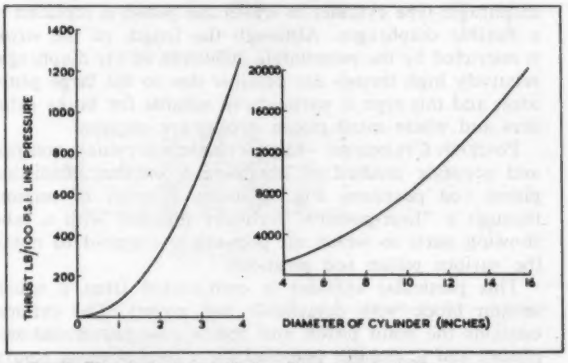


Fig. 7. Thrust against cylinder diameter at air line pressure of 100 p.s.i. Theoretical figures obtained from graphs should be reduced at least 20 per cent to allow for friction losses and pressure drop.

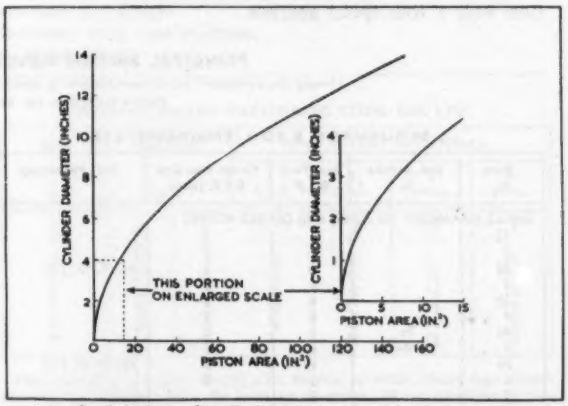


Fig. 8. Relation of cylinder diameter and piston area.

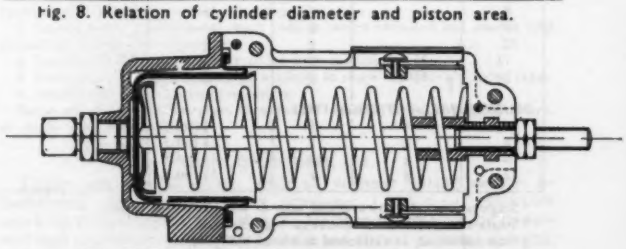


Fig. 9. Section through a Drayton thruster.

piston can be performed by external springing or by other means, larger strokes and bores are possible.

DOUBLE-ACTING—This type is used when it is required to exert a push and pull of a heavier nature, as in the opening and closing of furnace doors, press operation, power-assisted steering, and many other varied applications. In the double-acting cylinder air is admitted to one side of the piston, exhaust taking place on the opposite side of the piston via an air connection, and the return stroke is effected by reversing the air supply and exhaust.

TANDEM OR DOUBLE-IMPULSE—These are, in effect, two cylinders arranged back to back and the two pistons can be arranged to operate independently or both together. A typical application for this type would be where a work piece is to be moved in two stages for automatic drilling operations.

DOUBLE-ENDED PISTON ROD CYLINDER—With a fixed cylinder, movement of the piston imparts a push to one piston rod and a simultaneous push to the other. A particular application would be where one piston rod is arranged to operate a drill feed while the other piston rod is used to trip the necessary valves to operate a circuit sequence.

DIAPHRAGM-TYPE—Fig. 5 shows a section through a diaphragm-type cylinder in which the piston is replaced by a flexible diaphragm. Although the length of the stroke is restricted by the permissible deflection of the diaphragm, relatively high thrusts are possible due to the large piston area, and this type is particularly suitable for brake cylinders and where small piston strokes are required.

POSITION CYLINDERS—These cylinders provide a compact and accurate method of obtaining a number of distinct piston rod positions. Fig. 4 shows a series of sections through a "four-position" cylinder together with a table showing parts to which air pressure is supplied to obtain the various piston rod positions.

This particular cylinder is constructed from a square section block with detachable end covers. The cylinder contains the main piston and rod, a free piston and stop piston, and is usually operated by a four-position rotary-type valve. Air is admitted to two or three of its four ports, depending on the piston position required. A typical installation for this type of cylinder would be in conjunction with a four-speed gearbox.

Another type of positioner is shown in Fig. 10, this particular diaphragm-type actuator being suitable for positioning mechanisms with low force characteristics, e.g., engine throttling and similar devices.

Cylinder Selection

Since the theoretical cylinder thrust is the product of piston area and pressure, a determining factor in the selection of cylinder sizes is the constant air pressure available for use at the piston. Curves are shown in Fig. 7 indicating the theoretical thrust for various cylinder diameters at an air-line pressure of 100 p.s.i., while Fig. 8 is a plot of cylinder diameter against piston area.

The thrust at other air line pressures may be estimated by multiplying the figures obtained from the graph by $\frac{P}{100}$, where P = air line pressure being considered. The average rate of air consumption may be calculated from the following expression:

$$C = \frac{(P + 14{\cdot}7) \times L \times A \times N}{1728 \times 14{\cdot}7}$$

where C = ft.³/min. of free air at atmospheric pressure; L = length of stroke (in.); A = piston area (sq. in.); N = number of single strokes/min.; and P = working pressure available at cylinder (p.s.i.).

Materials used in the cylinders should be compatible with the surrounding atmosphere and, where possible, protective gaiters should be fitted to the piston rods.

If the piston rod is intended to move through an arc (for example, when a cylinder is employed to open a door) or when any difficulty is anticipated in maintaining exact alignment of the cylinder assembly, then trunnion mountings should be used. For fixed linear movement, foot mountings, neck and flange mountings are suitable.

When high compression loads are being considered, particular attention must be paid to the relationship between the piston rod diameter and the length of stroke, high stroke/bore ratios tending towards a "strut crippling", or bowing effect, on the piston rod. It should be noted that larger piston rod diameters will reduce the thrust in one direction due to the reduction in effective piston area.

PRINCIPAL BRITISH RANGES OF PNEUMATIC ACTUATORS

(Among the companies which manufacture to special order only are Gloster Aircraft Co., H. G. Somerfield Ltd., Electro-hydraulics Ltd. and Automotive Products Co. Ltd.)

J. BROUGHTON & SON (ENGINEERS) LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End B.S.F. (ext)	Std. Mountings
SINGLE (ARRANGED TO PUSH) AND DOUBLE-ACTING				
1½		¼	¼	
2		¼	¼	
2½		¼	⅜	A, C, G, J *‡
3		¼	⅜	
3½		⅜	⅜	
4		⅜	⅜	
4½	To	¼	⅜	
5	order	¼	⅜	
5½		¼	⅜	C, D, G, J †‡
6		¼	⅜	
7		⅜	1	
8		⅜	1¼	
10		⅜	1¼	
12		⅜	1¼	
1½	3½ & 7	¼	⅜	G †
2½	3½ & 7	¼	⅜	
DOUBLE-ACTING (DIAPHRAGM TYPE)				
4½	¼	¼	⅜ (int.)	
6	⅜	¼	⅜ (int.)	
8	¼	¼	1¼ (int.)	C, D §
12	⅜	¼	1¼ (int.)	

* Single-acting cylinders available with or without spring return.
† Single-acting cylinders without spring return.
‡ Non-cushioned, or cushioned at one or both ends.
§ Non-cushioned only.

DRAYTON REGULATOR & INSTRUMENT CO. LTD.

This company produces a light action cylinder suitable for damper control and similar operations, a special feature being an adjustable stroke. Cylinder is of diaphragm single-acting spring-return type, with a standard stroke of 2¼ in., giving a minimum thrust of 15 lb. in either direction, under the normal air pressure range of 5-10 p.s.i. Maximum overload pressure: 30 p.s.i. Adjustment to piston stroke is made externally (see Fig. 9), and is effective for either end of travel. Air inlet is suitable for a solderless union with ¼ in. o.d. pipe; weight is 2 lb. 6 oz. with an overall closed length of 8 in. Alternative pressure ranges available.

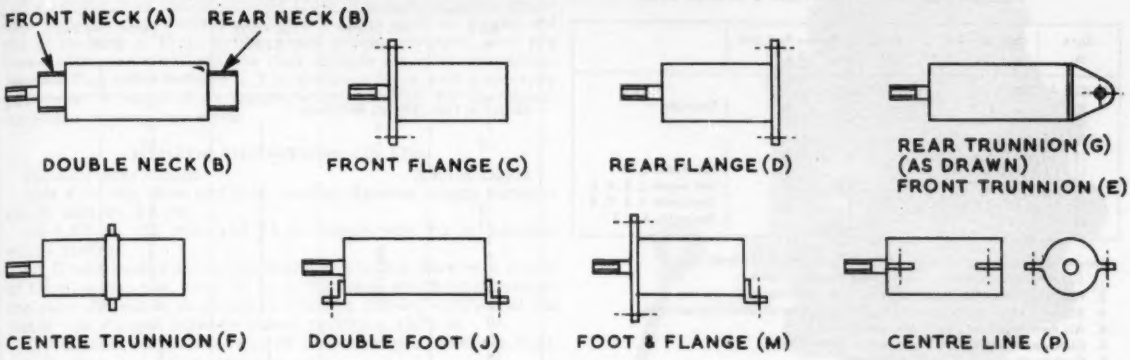
BALDWIN INSTRUMENT CO. LTD.

Bore in.	Std. Port B.S.P.	Piston Rod End B.S.F.	Std. Mountings
DOUBLE-ACTING			
1½	¼	⅜	
2½	¼	⅜	C, D, E, F, G, J
3	⅜	⅜	
4½	¼	1	
6	⅜	1¼	
8	1	1¼	

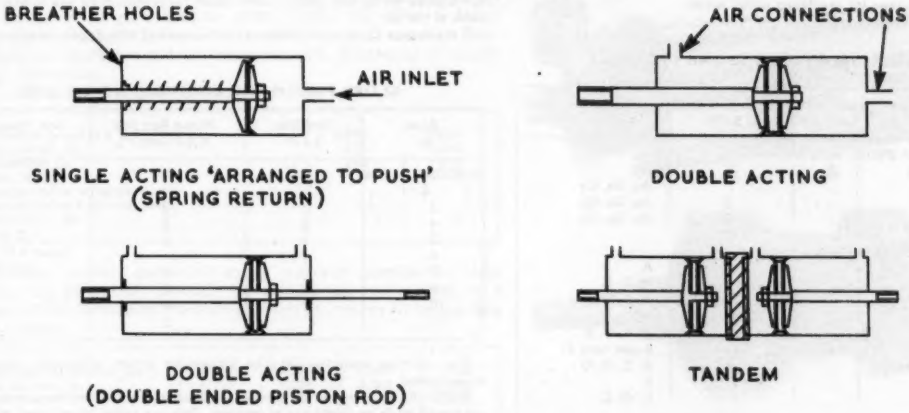
All obtainable in single and double piston rods. Cushioned at front and/or rear end, or non-cushioned.

Max. operating pressure: 150 p.s.i. Strokes to order. Super-cushioned cylinders available.

CYLINDER MOUNTINGS



CYLINDER TYPES



KEY TO MOUNTINGS CODE USED IN THESE TABLES

A—Front neck: (a) arranged to push; (b) to pull.
B—Double neck: (a) arranged to push; (b) to pull.
C—Front flange: (a) arranged to push; (b) to pull.
D—Rear flange: (a) arranged to push; (b) to pull.
E—Front trunnion: (a) arranged to push; (b) to pull.
F—Centre trunnion: (a) arranged to push; (b) to pull.
G—Rear trunnion: (a) arranged to push; (b) to pull.
H—Front flange, rear neck: (a) arranged to push; (b) to pull.
J—Double foot: (a) arranged to push; (b) to pull.
K—Front neck, rear flange: (a) arranged to push; (b) to pull.
L—Rear trunnion with enlarged piston rod: (a) to push; (b) to pull.
M—Foot and flange.
O—Front neck, rear trunnion.
P—Centre-line.

BURNLEY AIRCRAFT PRODUCTS LTD.

The cylinders produced by this company are designed specifically for use with their various welding machines and accessories. They incorporate double pistons, one giving a high clearance lift to the welding electrode, and the other providing the short stroke to apply constant welding pressure for the welding cycle.

CLAYTON DEWANDRE & CO. LTD.

Piston type		Diaphragm Type		
Bore in.	Std. Stroke in.	Effective diaphragm area (in.²)	Overall dia. in.	Max. Stroke in.
SINGLE-ACTING (ARRANGED TO PUSH)				
2½	2½	6	4⅞	1½
2⅝	1	9	5½	1⅝
3	2½	12	5⅛	1⅝
3½	1⅝	16	6⅜	2½
4	2½	20	6⅛	2½
4	3½	24	7½	2½
4	5	30	8½	2½
4½	2½	36	9	3
4½	1⅝			
4½	2½			
5	2½			
5½	2½			
6	2½			
6	5·1			

Primarily intended for pneumatic braking circuits, but satisfactory for many other duties. The diaphragm type are Bendix-Westinghouse components made under licence by Clayton Dewandre.

CONSOLIDATED PNEUMATIC TOOL CO. LTD.

Bore in.	Std. Port B.S.P.		Piston Rod End Threads (Ext.) 1 B.S.F.	2 Whit.	3 Whit.	4 Whit.
2½	¼	—	—	⅜	⅜	⅜
3	¼	—	—	½	½	½
4	¼	¼	1½	½	½	1½
5	¼	⅜	1½	½	1½	1½
6	⅜	⅜	1½	1½	1½	1½
7	⅜	1½	1⅜	1½	1⅜	1⅜
8	⅜	1½	1⅜	1½	1½	1⅜
9	⅜	1½	2	1⅜	1½	1⅜

Max. operating pressure: 80-100 p.s.i. Strokes to order. Heavy-duty models available (not indicated here) for loads up to approx. 38 cwt. Single-acting type raising under pressure and lowering by gravity.

1. Double-acting, cushioned at both ends in centre trunnion and double foot mountings (cushioning adjustable).
2. Double-foot mounting, double-acting (non-cushioned).
3. Front and rear flange mountings, available in single- and double-acting types.
4. Double-acting rear trunnion mounting.

Piston rod end can be left plain, threaded as required, fitted with yoke or eye, or fitted with clamping plate.

DUNLOP RUBBER CO.

Single- and double-acting, with or without spring return or cushioning. Maximum working pressure: 1,500 p.s.i. Minimum working temperature: — 60 deg. C. Designed primarily for undercarriage operation, jet engine control and thrust reversal systems, radiator flap actuation, etc.

"BRITISH BELLOWS" (BENTON & STONE LTD.)

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End B.S.F.	
SINGLE-ACTING				
1½	1, 2, 3, 4	—	7/16	See note 1
DOUBLE-ACTING				
1½	1, 2, 3, 4, 5, 6	—	7/16	
1¾	1, 3, 6, 9, 12	¼	⅜	See notes 2, 3, 9
2½	1, 3, 6, 9, 12	¼	⅜	See notes 2, 3, 4, 5
2½	6	¼	⅜	See notes 3, 6, 7, 8
3¾	—	—	—	See notes 3, 4, 5

Numerous mountings possible without additional brackets.

1. Supplied with built-on "maintained contact" valve.
2. Non-standard strokes up to 36 in. max. to order.
3. Built-in valve, with manual, air-pilot operated or electrical control.
4. Air flow regulators built into valve.
5. Cushioned (adjustable) at either or both ends.
6. Cushioned at end of outward stroke.
7. Stroke up to 9 in. max. to special order.
8. Incorporating quick exhaust valve and air accumulator, providing high piston speed.
9. Built-in throttle screws for regulating piston speed.

"ENOTS" (BENTON & STONE LTD.)

Bore in.	Std. Stroke in.	Std. Port tube o.d.	Piston Rod End B.S.F.	Std. Mountings
SINGLE-ACTING WITH SPRING RETURN				
¾	1, 2, 3	7/16	7/16	Aa
1¼	,,	,,	,,	Aa, Da, Ga
2¼	,,	,,	⅜	Aa, Ga, Ka
3	,,	,,	⅜	Aa, Ga, Ka
DOUBLE-ACTING, NON-CUSHIONED				
¾	1, 2, 3, 6, 9, 12	7/16	7/16	A
1¼	1, 2, 3	,,	,,	A, D, G
1¼	6, 9, 12	,,	¼	A, K, O
2¼	1, 2, 3, 6, 9, 12	,,	,,	A, D, G
3†	,,	,,	⅜	A, B, G, K
3	—	¼	1	E (see note 4)
4¼	1, 2, 3, 6, 9, 12	,,	¼	A, C, D, G
4¼	,,	,,	1	E
6	,,	,,	1	C, D, G
DOUBLE-ACTING, CUSHIONED				
3	3–84	7/16	⅜	A, G, K*
3	12–84	,,	,,	B*
DOUBLE-ACTING, WITH DOUBLE-ENDED PISTON RODS†				
1¼	1, 2, 3	7/16	7/16	B
2¼	1, 2, 3, 6, 9, 12	,,	⅜	A
3	—	,,	⅜	B*
4¼	1, 2, 3, 6, 9, 12	¼	½	P
6	,,	¼	1	P
DOUBLE-ACTING DUPLEX CYLINDERS†				
1¼	1, 2, 3, 6, 9, 12	7/16	⅜	B
2¼	,,	,,	⅜	—
3	—	,,	⅜	B
4¼	1, 2, 3, 6, 9, 12	¼	½	P
6	,,	,,	1	P

* Cushioned at either or both ends of cylinders as required.

† To special order only.

Max. working pressures: ¾, 1¼, 2¼ and 3 in. bore—150 p.s.i.; 4¼ in.—120 p.s.i.; 6 in.—100 p.s.i. Max. working temperature: 120 deg. C.

All double-acting cylinders with strokes other than standard to special order (84 in. max.).

E.M.B. CO. LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End B.S.F. (int.)	Std. Mountings
SINGLE-ACTING (SPRING RETURN, ARRANGED TO PUSH)				
4	4	¼	¼	Ca, Da, Ea, Ga
6	4	¼	⅜	
8	4	⅜	⅜	
12	6	1	1½	Ca, Da, Ja
16	6	1	1½	
DOUBLE-ACTING				
4	4, 8	¼	¼	C, D, E, G, J
6	4, 8	¼	⅜	
8	4, 8	⅜	⅜	
12	6, 12	1	1½	C, D, J
16	6, 12	1	1½	

All cylinders with direct acting or variable speed control (except 4 in. bore, which has direct-acting only).

Max. working pressure: 100 p.s.i.

STUART DAVIS LTD.

Bore in.	Std. Stroke in.	Std. Ports B.S.P.	Piston Rod End B.S.F.	
			Non-cushd.	Cushioned
SINGLE-ACTING (SPRING RETURN)†				
1	1	¼	⅜*	
1½	1	¼	⅜*	
DOUBLE-ACTING‡				
1	To order	¼	7/16	7/16
1½		¼	⅜	⅜
2½		¼	⅜	⅜
3		⅜	⅜	⅜
4		⅜	⅜	⅜
5		¼	⅜	⅜
6		¼	1	1
8		⅜	1	1
10		1	1¼	1¼
12		1	1¼	1¼
14		1	2	—

Max. operating pressure: 150 p.s.i.

* Piston rod end plain diameter.

† Clamps for jig and fixture work. Rear flange mounting and locating holes at sides of barrel.

‡ Mountings D, G, or J. Cylinders can be supplied with double-ended piston rod.

GLOBE PNEUMATIC ENGINEERING CO. LTD.

Bore in.	Port Size B.S.P.	Piston Rod End B.S.F. (ext.)	Std. Mountings
DOUBLE-ACTING			
2	¼	¼	C,D,F,G (over 3 in. bore, also J)
3	¼	⅜	
4	⅜	⅜	
5	¼	7/16	
6	¼	1	
7	¼	1¼	
8	¼	1¼	
10	⅜	1¼	
12	1	1⅜	

Max. working pressure: 120 p.s.i. Strokes to order. Available non-cushioned or cushioned.

NOTE: Although not in the category of linear actuators, two types of compressed air motor made by Globe are of interest. One is a radial piston type, the other a V-type piston motor. The radial motor is available in seven sizes in $\frac{3}{8}$ to 10-h.p. range, and the V-type is in four sizes from ¼ to 1½ h.p.

HYDRAULICS & PNEUMATICS LTD.

The clamp-type cylinders are of unusual design, employing a square body which may be fixed in any plane, to allow multiple units to be mounted close together. Bore size is 1½ in. dia., and strokes of 1 in. or 2 in. are available. Piston is single-acting, with spring return.

The Modernair stud-mounted double-acting cylinder has 1½ in. bore, the stroke being to order up to 24 in. Maximum working pressure is 200 p.s.i., and the cylinder is provided with a screwed spigot at the ram end for mounting purposes. The Modernair Economair series of cylinders are double acting (available with cushioning when required at either or both ends) and have a screwed mounting spigot at both ends. A series of end fittings is available to suit every type of mounting requirement. Piston strokes are as ordered, while the bores are standardised at 1½ in., 1¾ in., 2 in., 3 in. and 4 in. dia.

The Provenair series are double-acting cylinders with cushioning if required at either or both ends of the stroke and, like the Economair range, provision is made for a variety of standard mounting attachments. Standard bores available are 4 in. and 6 in. dia. Strokes are to order.

JOHN LANG & SONS LTD.

The rotating air cylinders manufactured by this company are primarily for use in conjunction with power-operated chucks, but their relatively short strokes and compact nature may be suited to other applications:

Bore, mm.	150	200	250	300	350
Stroke, mm.	32	32	32	32	32
Pull on piston rod at 85 p.s.i., lb.	2,100	3,860	6,175	8,825	12,125

A range of tandem air cylinders is also available and is particularly suited for use on automatic chucking lathes and where the cylinder diameter is limited.

JAMES GORDON CO. LTD.

Two of the most commonly used types of pneumatic servo actuators made by this company are the 5 in. bore × 10 in. stroke and the 2½ in. bore × 10 in. stroke. These provide for open, shut and intermediate positions and are thus suitable for valve operations. A smaller type of 3 in. bore × 3 in. stroke is fitted with a cam-type positioner. A range of air motors is also available for the power operation of very large valves.

HYMATIC ENGINEERING CO. LTD.

Standard jacks include:

(a) 1·4 in. dia. bore and 3 in. stroke. Approx. length between closed centres, 8·5 in.

(b) 2·375 in. dia. bore and 3·5 in. stroke with 9·5 in. between closed centres.

(c) Double-ended piston rod model of 2 in. dia. bore with stroke of 1·4 in. at one end, and 1·97 in. at the other end (both moving in the same direction). A linkage is fitted to prevent rotation of the piston rod. Length between closed centres is 12·75 in.

Typical uses: operation of aircraft undercarriages and doors, flaps, fuel jettison and other emergencies.

Snap jacks are available, consisting of a combined ram and air bottle with integral pressure gauge, indicating maintenance of pressure. Pressure is retained in the air bottle by a metal diaphragm supported by a frangible tubular pillar. When the pillar is burst explosively by the application of 12-24 volts d.c. to a contained fuse, the diaphragm fractures and air enters the ram, extending it rapidly through its stroke.

Two models are available, as follows:

Air storage pressure, p.s.i.	1,800	2,000
Initial thrust, lb.	630	1,750
Final thrust, lb.	550	830
Stroke, in.	3	7·75
Min. stop valve voltage	½	½
Min. stop valve current, amp.	½	½
Total weight, lb.	1·6	2

Four other models, each with an air reservoir outside the main cylinder, are operated remotely by mechanical means such as a Bowden cable. Air is thus transferred from the reservoir to the face of the piston.

Air storage pressure, p.s.i.	3,000	3,000	2,000	3,000
Initial thrust, lb.	4,750	9,000	2,800	14,000
Final thrust, lb.	1,250	2,200	800	4,000
Stroke, in.	3	6	2	6
Stored energy, ft. lb.	600	2,280	260	3,580
Weight, lb.	2·6	3·72	2·3	4·5

These jacks can be used for emergency canopy release and fuel jettison.

Rotary actuators are also available whereby linear movement is converted to a torque, thus making them suitable for operating valves, etc.

PNEUSPEED LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End B.S.F.	Std. Mountings
DOUBLE-ACTING				
1½	To order	¼	$\frac{7}{16}$	A, G, J
2½		¼	½	A, G, J
3		¼	½	A, G, J
4		¼	⅝	A, G, J
6		½	1	D, G
8		⅜	1¼	G
8		½	1⅝	D

Tie-rod construction. Cushioning provided on return stroke if required. Single-acting cylinders available in short strokes. Port sizes also to special order.

F. PRATT & CO. LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End int. B.S.F.
DOUBLE-ACTING, NON-CUSHIONED			
2	1	¼	$\frac{7}{16}$
2½	1	¼	$\frac{7}{16}$
3	1	¼	⅝
4½	1	¼	⅝
6	1	¼	1
8	1	¼	1
10	1	¼	1¼
12	1	¼	1¼
14	1	¼	1¼

Std. mountings J, P, D, C, G. All can be supplied with cushioning at one or both ends. Cylinders of larger bore and stroke can be supplied; also special rotating cylinders for use in power chucking.

Fig. 10. A selection of typical actuators made in this country. From top of page: a Broughton double-acting diaphragm-type cylinder; pneumatic jack with hand-operated built-in valve by Benton & Stone; Baldwin double-acting cylinder with centre trunnion mounting; Teddington actuator with bellows; Schrader single-acting push-type spring-return air cylinder with single foot mounting.

ARNOLD GOODWIN LTD.

Bores from 1-18 in. diameter. Strokes to order up to 6 ft. All single- or double-acting, cushioned or non-cushioned. Mountings: C, D, G, J. Piston rod ends threaded or plain. Maximum working pressure: 150 p.s.i.

LANG PNEUMATIC LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Pistor Rod End B.S.F.	Std. Mountings
SINGLE-ACTING (SPRING RETURN)				
⅝	1 only	¼	7/16	Ba
1½	1 max.	¼	⅜	Aa, Da, Ga
2½	1½ max.	¼	⅜	Aa, Da, Ga
3	2 max.	¼	⅜	Aa, Da, Ga
SINGLE-ACTING (WITHOUT SPRING RETURN)				
1	To Order	¼	7/16	A, G
1½	1	¼	⅜	A, Bb, C, D, F, G, H, L
2½	1½	¼	⅜	
3	2	¼	⅜	
4	3	⅜	½	
5	3	⅜	½	C, D, F, G, J
6	3	⅜	1	
8	4	⅜	1¼	
10	4	½	1¼	C, G, J
DOUBLE-ACTING				
1	To order	¼	7/16	A, B, G
1½	,,	,,	⅜	A, B, E, G, C, D, J
2½	,,	,,	⅜	
3	,,	,,	⅜	
1½	1	,,	⅜	A, B, D, F, G, H
1½	6	,,	⅜	C, L
2½	1½	,,	½	A, B, D, F, G, H
2½	6	,,	½	C, L
3	2	,,	⅜	A, B, D, F, G, H
3	6	,,	½	C, L
4	3	⅜	,,	C, D, F, G, J
5	3	⅜	,,	
6	3	⅜	1	
8	4	⅜	1¼	
10	4	½	1¼	C, D, G, J
12	6	⅜	1¼	C, D, G
14	6	½	1¼	D
DOUBLE IMPULSE				
1	1 × 1	¼	7/16	
1½	1 × 1	¼	⅜	
2½	1½ × 1½	¼	⅜	
3	2 × 2	¼	⅜	
4	3 × 3	⅜	½	
5	3 × 3	⅜	½	
6	3 × 3	⅜	1	
8	4 × 4	⅜	1¼	
CUSHIONED (ADJUSTABLE CUSHIONING FRONT AND/OR REAR)				
1½	1*	¼	⅜	A, B, C, D, F, G
2½	1*	¼	⅜	
3	1*	¼	⅜	
4	1½*	⅜	½	
5	1½*	⅜	½	C, D, F, G, J
6	1½*	⅜	1	
8	2*	⅜	1¼	

* Standard length of cushioning. Strokes to order.
Oversize piston rods and threads available. Special strokes to order.

MAXAM POWER LTD.

Bore in.	Std. Strokes in.	Std. Port B.S.P.	Piston Rod End B.S.F. (ext.)	Std. Mountings
SINGLE-ACTING				
⅝	½, 1, 1½	¼	7/16	Aa, Ca, Da, G
DOUBLE-ACTING (NON-CUSHIONED)				
⅝	To order	¼	7/16	A, C, D, G
1½	1, 3, 5	¼	7/16	No 5-in. strokes in C and D mountings
2½	1, 3, 5	¼	7/16	
3	2, 4, 6	¼	7/16	
DOUBLE-ACTING (WITH ADJUSTABLE CUSHIONING)				
1½	To order	¼	⅜	A, C, D, G
2½		¼	⅜	
3		¼	⅜	
4		½	1	C, D, G, E, J and direct mounting
5		½	1½	
6		½	1½	
			Whit.	
8		½	2	C, D, E, J
10		½	2	
12		½	2	

Max. working temperature: 130 deg. C.

SPEED TOOLS LTD.

Designed specially for an air-operated toggle action clamp known as the Speetog, the actuator produced by this company combines a double-acting cylinder with adjustable cushioning at both ends of the stroke.

Cylinder bore is 1½ in. diameter; it has an effective stroke of 1½ in., and an overall weight of 3 lb. 3 oz. Inlet port is tapped ⅛ in. B.S.P.

MARTONAIR LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End B.S.F.	Std. Oper. Press p.s.i.	Std. Mountings
SINGLE-ACTING (SPRING RETURN)					
⅝	1	¼	7/16	60–150	Aa
1½	1½, 2½	⅜	⅜	30–100	Aa, Ca, Da, Ea, Ga, Ja
1⅞	2	¼	7/16	30–100	
2½	2	⅜	⅜	30–100	
DOUBLE-ACTING					
1½	1½, 3, 4½, 6	¼	⅜	30–100	A, C, D, E, G, J
1⅞	3, 6, 9, 12	¼	7/16	30–100	
2½	,,	⅜	⅜	30–100	A, C, D, E, F, G, J
2	and	¼	⅜	30–150	C, D, E, G, J
2½	to	⅜	½	,,	A, C, D, E, F, G, J
3	order	⅜	½	,,	
4	,,	⅜	1	,,	
5	,,	½	1½	,,	A*, C, D, E, F, G, J
6	,,	½	1½	,,	
8	,,	½	1½	,,	C, D, E, F, G, J
10	To order	1	2	,,	C, D, F, G, J
12	To order	1	2	,,	
HEAVY-DUTY, DOUBLE-ACTING					
2	To order	¼	½	250 max.	A, C, D, E, F, G, J
2½		⅜	½	,,	
3		½	½	,,	
4		½	1	,,	
5		½	1	,,	
6		½	1½	,,	
8		1	1½	,,	C, D, E, F, G, J
8		1	2	,,	
8		1	2½	,,	

Adjustable cushioning at both ends of stroke for double-acting cylinders. Internal or shouldered threads available at piston rod ends.
*This mounting supplied only on request.
† Double-ended and tandem types available, except for 1½, 1⅞, and 2½-in. bore models.

A. SCHRADER'S SON DIV. OF SCOVILL MFG. CO.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End	Std. Mountings
*SINGLE-ACTING (ARRANGED TO PUSH AND SPRING RETURN)**				
			(plain)	
1	1 & 2	⅛	7/16	
2½	,,	¼	⅜	J
3	,,	¼	⅜	
SINGLE-ACTING (SPRING RETURN OR NO SPRING RETURN)				
			B.S.F. ext.	
1½	1, 2, 3, 4, 5	¼	⅜	G
2½		⅜	⅜	
DOUBLE-ACTING				
1		¼	⅜	
1½	1, 2, 3, 4, 5, 6,	¼	⅜	C
2½	and to order	⅜	⅜	G
3		⅜	1	J
4		½	1	

Max. working pressure, 150 p.s.i.
* Clamping cylinder for jigs and fixtures, etc.

PALMER AERO PRODUCTS LTD.

Bore in.	Stroke in.	Max. thrust, lb.		Pressure p.s.i.
		Extension	Retraction	
11/16‡	1	77	6½ (spring return)	350
11/16	1	77	12½ (spring return)	350
11/16‡	1	77	12½ (spring return)	350
1·4	2	539	499	350
2⅛	2·5	1,550	1,481	350
1·4	3	539	499	350
1·4	2	539	90 (spring return)	350
2⅛†	4·75	2,079	2,010	350
2⅛†	3·5	2,079	2,010	350
2⅛*	4·5	2,673	2,584	450
1⅛*	2	1,082 (spring action)	1,033	450
1⅛*	2	80§ (start) 28 (finish)	950 approx.	450
2†	16·75	1,300 max.	900 max.	450

* For rear trunnion mounting.
† Self-aligning bush fitted in rear trunnion mounting. Remainder are fitted with a universal ball joint with a threaded extension, with the exception of those marked ‡ which are rigidly fixed through the cylinder body.
§ Embodies a built-in cut-off valve which gives variation in thrust.
Inlet ports are threaded to ¼ in. B.S.P. and the jacks are designed to operate within a wide range of temperatures.

MIDLAND PNEUMATIC CO. LTD.

Bore in.	Std. Stroke in.	Std. Port B.S.P.	Piston Rod End B.S.F.	Std. Mountings
SINGLE-ACTING WITH SPRING RETURN				
1½	1 max.	¼	⅜	Aa, Da, Ga
2½	1½ max.	¼	½	
3	2 max.	¼	⅜	
SINGLE-ACTING WITHOUT SPRING RETURN				
1½	1	¼	⅜	A, Bb, D, G, Hb
2½	1½	¼	½	
3	2	¼	⅜	
4	3	⅜	½	C, D, F, G, J. Tie-rod
5	3	⅜	½	
6	3	⅜	1	
8	3	⅜	1½	
DOUBLE-ACTING				
1	To order	¼	$\frac{7}{16}$	A, G
1½	1	¼	⅜	A, B, C, D, F, G, H
2½	1½	¼	½	
3	2	¼	⅜	
4	3	⅜	½	C, D, F, G, J. Tie-rod.
5	3	⅜	½	
6	3	⅜	1	
8	3	⅜	1½	
DOUBLE-ACTING DUPLEX CYLINDERS				
1½	1	¼		
2½	1½	¼		
3	2	¼		
4	3	⅜		Trunnion mounting at both ends.
5	3	⅜		
6	3	⅜		
8	3	⅜		

Piston rod threads are nominal. O/S threads and rods available with certain models. Cushioned cylinders available 1½-in. to 8-in. bore, in any standard mounting. Other strokes to special order.

TEDDINGTON AIRCRAFT CONTROLS LTD.

The single-acting spring-return jack type FBG, with a built-in electrically-operated air valve, is fitted with a universal joint for attachment. With a stroke of 2⅝ in., a minimum pull of 120 lb. at 350 p.s.i. can be exerted, the spring-return push of 20 lb. diminishing to 12 lb. at the end of the stroke. This jack is made in several forms with varying operating voltages, inlet union size and piston rod end fittings.

A more powerful single-acting spring-return jack, type EY, exerts a force of 380 lb. through a 3-in. outward stroke and a force of 64 lb., diminishing to 19 lb., on the spring-return stroke. Non-standard strokes and piston rod lengths can be supplied to order, and the internal return spring may be omitted when the jack is used with mechanisms which themselves supply the returning force.

The double-acting type FBC, with a stroke of 1½ in., exerts a force of 1,450 lb. on the outward stroke and 1,400 lb. on the inward stroke at 350 p.s.i. Available with ⅛ and ¼ B.S.P. air connections, the weight is 31 oz.

Type FQ is a double-acting jack with a built-in electrically-operated pneumatic valve, designed for manual switching or automatic control by means of a thermostatic or other self-operating switch. The jack extends with the current "on", and retracts with current "off"; hence electrical supply failure ensures pneumatic locking of the jack in the fully retracted position. The rear eyebolt fitting has a self-aligning bush. The force on the outward stroke is 1,020 lb., with 1,000 lb. on the inward stroke at 350 p.s.i. Standard strokes are 2 in. and 3 in., but any stroke not exceeding 3 in. can be supplied to order. Variation in operating voltages, union size and relative position of union and eyebolt is possible.

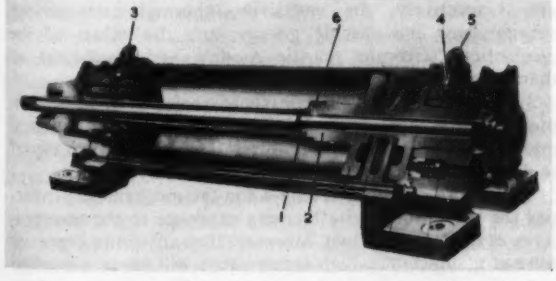


Fig. 11. Section through Lang Pneumatic double-acting cylinder with adjustable cushioning at both ends of stroke. Cushioning mechanism shown is (1) piston pad, (2) piston, (3) control valve, (4) control needle seal, (5) control needle locknut, and (6) piston cup.

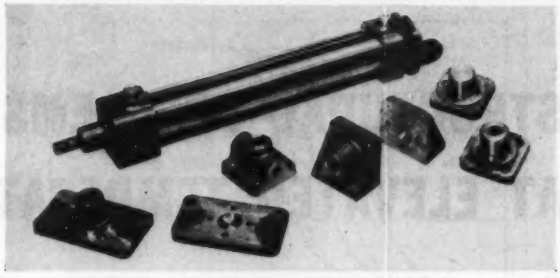


Fig. 12. Lang Pneumatic double-acting cylinder of basic unit type with range of standard mountings.

PLESSEY CO. LTD.

A wide variety of air-motor-driven actuators are available incorporating a lobe-type motor and a recirculating ball system converting rotary motion to a linear thrust. Typical of these is a ram developed to give 5,000 lb. thrust, the 5-in. stroke being completed in less than 1 sec. A further model to give a 0·6-in. stroke and 100 lb. thrust in ½ sec. weighs 4 lb.

UNITED STATES METALLIC PACKING CO. LTD.

Bore in.	Std. Port B.S.P.	Piston Rod End B.S.F.		Std. Mountings
		Ext.	Int.	
SINGLE- AND DOUBLE-ACTING				
1½	¼	$\frac{7}{16}$	$\frac{7}{16}$	C, D, J (non-cushioned)
1½	¼	$\frac{7}{16}$	$\frac{7}{16}$	
2	¼	⅜	½ or ⅜	
2½	¼	⅜	½ or ⅜	
3	⅜	⅜	½ or ⅜	
3½	⅜	1	⅝ or 1	
4	¼	1	⅝ or 1	C, D, F, G, J (for double-ended piston-rod), P, M
4½	¼	1	⅝ or 1	
5	¼	1	⅝ or 1	
6	¼	1½	⅞ or 1½	
7	⅜	1⅜	⅞ or 1⅜	
8	⅜	1½	1 or 1½	See note 1
9	⅜	1½	1 or 1½	
10	⅜	1½	1 or 1½	
12	1	2	1½ or 2	
14	1	2½	1½ or 2½	

NOTE: Strokes (¼ in. to 12 ft.) to order.

Cylinders of the pendant type made by this company are fitted with safety check valve to prevent movement of load in event of failure of air supply or break in hose.

Max. operating pressure: 120 p.s.i.

1. Balanced pressure types also available, and either non-cushioned or cushioned at one or both ends of cylinder. Cushioning is adjustable.

WADE ENGINEERING LTD.

The Wade air motor, designed to operate on air pressures of between 3-10 p.s.i., will develop up to ½ h.p., and is fully reversible with instant starting and stopping. It is therefore highly suitable for the operation of linear actuators where only a low pressure is available and fire risks preclude the use of electric actuators.

WESTINGHOUSE BRAKE & SIGNAL CO. LTD.

DOUBLE-ACTING

Diameters ranging from 1½" to 10" with strokes to suit requirements. Various mounting arrangements. Available with or without cushioning. Maximum operating pressure 120 p.s.i.

POSITIONING DEVICES

Infinite positioning for a wide variety of applications is achieved by a range of units catering for negligible resistance to movement, up to servo units with ratings of 625 lb. with 6 in. stroke.

BRAKE CYLINDERS

Sizes to suit vehicles of various weights and types, including diaphragm and piston-operated cylinders. Available for various types of brake riggings or for back plate mounting.

STRUCTURAL PROBLEMS AT ELEVATED TEMPERATURES

The complexity of thermal stressing is being increasingly recognised in many spheres of industry. This article discusses the parameters that may have to be considered by the designer when high temperatures are involved

by D. J. JOHNS, B.Sc., M.I.A.S., Grad.R.Ae.S.*

WHEN relative motion exists between a body and a fluid (gas or liquid), the layer of fluid adjacent to the body is decelerated by viscous forces causing an increase in fluid temperature as the body surface is approached. Heat may therefore be transferred to the body and its temperature will rise to an equilibrium value for steady external conditions.

In most branches of engineering, e.g., chemical, steam, etc., this equilibrium body temperature may be approximated by the ambient temperature (T) of the fluid, since the fluid velocity is generally low and there is no appreciable kinetic effect. Also, the temperature-time response of the body surface is usually sufficiently low as to introduce no major transient effects.

In aircraft engineering the problem is more complex for two main reasons. First, the fluid velocities can be so great as to cause the body temperatures to be much larger than the fluid ambient value. For air, the maximum fluid temperature (T_H) is related to the ambient temperature (T) and Mach number (M) as follows:

$$\frac{T_H}{T} = 1 + \frac{M^2}{5} \qquad (1)$$

Table 1 gives values of T_H for T = 15 deg. C. and T = 0 deg. C. and various M. At higher Mach numbers, dissociation effects in air become more important; Table 2 presents some useful results. The temperatures quoted become increasingly less than those predicted for non-dissociating flow using the conservative relationship of Equation 1.

The second reason is that the accelerations of high-speed aircraft, particularly missiles, cause considerable transient effects, notably large temperature gradients within a structure due to differences in temperature response.

In fact, in air the maximum structure temperature (or adiabatic wall temperature $= T_w$) is always less than the maximum fluid temperature (or stagnation temperature $= T_H$) by an amount which depends upon the boundary layer state, Reynolds number and fluid temperature, as is indicated in Table 1.

TEMPERATURE RESPONSE—The temperature response of any element of a structure depends primarily on its heat capacity which is proportional to the product of density and specific heat, and also on the correct knowledge of the various modes of heat transfer, particularly kinetic heating. The kinetic heat transfer (q) is determined by using Newton's Law of Cooling with T_w as a measure of the heat intensity, i.e., $q = h(T_w - T_s)$. The heat transfer factor (h) is a function of skin friction coefficient, flow velocity, surface-temperature (T_s) and ambient flow properties. It is still imperfectly known and is the cause of most inaccuracy in heat transfer analysis. Values of h are discussed in [1–4].

Other modes of heat transfer are emitted radiation loss, which is only important for surface temperatures greater than 200 deg. C., absorbed solar radiation (generally negligible), and convective, conductive and radiative heat transfer within the structure. Hoff[5] has compared the effects of the last two modes and his results indicated that radiation could have a beneficial effect in reducing temperature gradients within the structure.

In an analysis considering only kinetic heat transfer the maximum value of the skin temperature, T_s, may be over 80 deg. C. less than the maximum value of T_w, and it occurs later. This indicates that in rapid heating and cooling problems the adiabatic wall temperature can at various times give fairly wide variations in the estimate of the skin temperature.

The temperature distributions within a complex structure are difficult and tedious to obtain. However, a recent paper[6] has shown that simplifications can be made by utilising assumed modes of temperature distributions in an energy-type approach. Such analyses have been made for I-section beams[7] and for stiffened cylindrical shells.[8]

Effect of High Temperatures on Material Properties

The material properties which most influence, and are most influenced by, the achievement of high temperatures are, respectively, the emissivity, thermal conductivity, specific heat and specific gravity, and the values of the mechanical strengths, elastic moduli and coefficient of thermal expansion.

Tables 4 and 5 summarise some useful information on physical and material properties of various structural materials at different temperatures. These tables are meant to be illustrative rather than comprehensive.

The values quoted in Table 4 for the mechanical properties are those obtained after long exposure to the temperatures quoted. It is known, however, that any finite exposure time at a sufficiently high temperature will cause a marked reduction in mechanical properties. Fig. 1 shows how the 0·1 per cent proof stress of a typical light alloy (D.T.D. 364) is a function both of temperature and exposure time.[9] Consequently, it must be emphasised that the material and

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physical properties assumed in any particular investigation must be realistic for the temperatures and exposure times anticipated in the particular application.

To emphasise the significance of heating rates on material properties, Fig. 2 has been obtained from various sources.[10] The alloy 75S is equivalent to D.T.D.687, and R.R.58 is a Hiduminium alloy classed as D.T.D.5070. The results for the 75S alloy show the significance of very high heating rates on material properties, and would suggest that the percentage loss of tensile strength of R.R.58 at the same rates should be remarkably low, particularly as the R.R.58 values quoted correspond to a mean heating rate of about 2 deg. C./sec.

Mention has already been made of the influence of exposure time and heating rate on mechanical properties. Other considerations may, however, influence the choice of material, for example, the effects of thermal cycling (repeated heating, cooling or heating). It may also be necessary to consider creep effects and to assess recovery values of the material properties at low temperature after exposure to high temperatures. Both [11] and [12] have considered the latter effect and it was shown that S.A.P (sintered aluminium powder: Hiduminium 100) has excellent characteristics, whereas R.R.58 and most other aluminium alloys are less satisfactory. The reduction of material properties due to high temperature naturally influences the behaviour of structural elements operating under conditions of uniform elevated temperatures. If the effects of thermal stress are neglected, various structural elements can be considered showing how their efficiency is affected solely by deterioration in material properties.

The efficiency of tensile elements depends simply on the value of specific strength or stiffness according to the criterion involved (see Table 4) or else on the appropriate creep and stress rupture data. Similar considerations apply in the case of torsional elements.

When the efficiency to resist buckling in compression or shear, for struts, integrally stiffened shells or plates, is considered, the criterion of efficiency is either

$$\frac{E^{\frac{1}{2}}}{\rho}, \frac{E^{\frac{1}{3}}}{\rho} \text{ or } \frac{G^{\frac{1}{3}}}{\rho}$$

depending on whether the mode of instability is in compression or in shear. Values of the above parameters in terms of the Youngs Modulus (E), the modulus of rigidity (G) and the density (ρ) can be deduced for various materials from [11].

Thermal Stress and Associated Problems

In transient heating a severe temperature difference may exist between, say, the outer shell plating and an internal web of the same material. The resultant thermal stress distribution is proportional to the temperature difference, the modulus of elasticity (E) and the coefficient of thermal expansion (α). The term "thermal stress modulus" has been applied to the product $E\alpha$ (see Table 4). However, even if no temperature gradients exist in a structure, thermal stresses may be set up due to the different coefficients of expansion of dissimilar component parts. In other words, thermal stresses are not only a transient effect.

In Ref. [12] a typical I-section was taken as an example and three alternative forms of construction were considered, i.e., (a) all steel; (b) all dural; and (c) steel skins, dural webs.

In each case the proportions were adjusted to give an approximately optimum structure for a given loading, depth and torsional stiffness. The thermal stresses are assumed to arise from an instantaneous change in velocity of the surrounding fluid to M = 2·5 after a long period at M = 1·25 at an altitude of 30,000 ft. Fig. 3 shows the stresses at the centre of the web and in the skin midway between webs. In the all-steel structure the high thermal

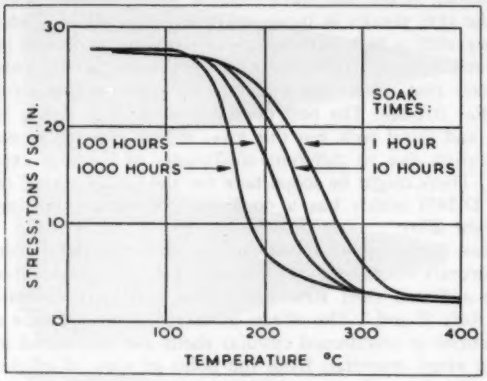


Fig. 1. 0.1 per cent proof stress of D.T.D.364 at elevated temperatures.

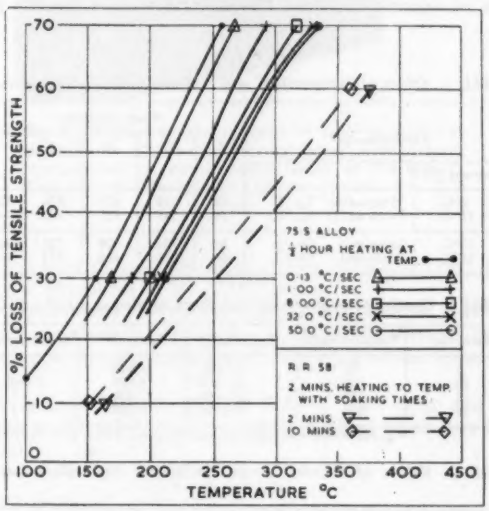


Fig. 2. Percentage loss of tensile strength from value at 15 deg. C. for different heating rates and soak periods.

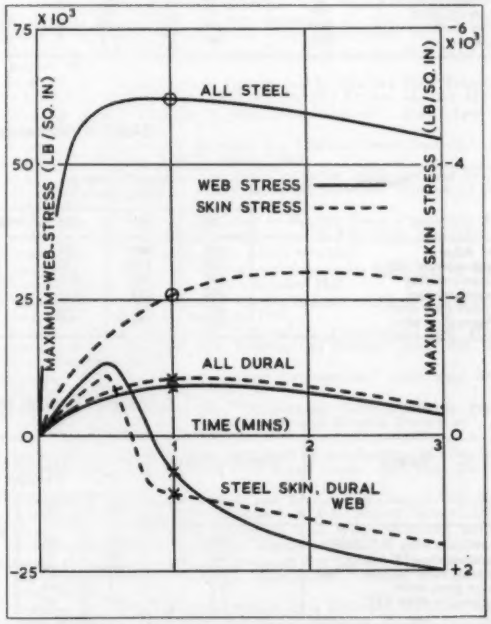


Fig. 3. Thermal stresses in a multi-web wing.

resistance of the thin webs coupled with low heat capacity of the skin results in large temperature gradients and, together with a high thermal stress modulus, produces large thermal stresses (60,000 p.s.i.) at the centre of the web. It is seen that other material combinations produce much smaller stresses. The best combination is that with a steel skin and dural web, but this gives a high residual stress at saturation due to different coefficients of thermal expansion. There might be scope here for the use of a steel (e.g., D.T.D.247) which has a coefficient of expansion similar to light alloy.

Most published work deals mainly with thermal problems on aircraft wing structures and relatively little deals directly with stiffened shell structures. Two particular exceptions are Refs. [13] and [8]. The effects of arbitrary temperature distributions in unstiffened circular shells are considered in [14].

To assess materials from the point of view of efficiency to resist thermal stress, various parameters are involved, i.e., thermal conductivity (k), coefficient of thermal expansion (α), specific heat, etc. Thermal stresses are directly proportional to the thermal stress modulus ($E\alpha$) and the higher the thermal conductivity, the lower they would be expected to be. In fact, the quantity involved is the thermal diffusivity, i.e., the thermal conductivity divided by the product of specific heat and density. For a given heat input, therefore, the resulting thermal stress would seem to be proportional to

$$\frac{\text{thermal stress modulus}}{\text{thermal diffusivity}}$$

This thermal stress coefficient was proposed in [11], and Table 3 presents values of the coefficient for five materials, (units: c.g.s. units $\times 10^3$). The relative order of magnitudes is also shown.

A similar approach in [15] relates the parameters, thermal stress modulus, thermal conductivity and specific ultimate strength to give thermal stress efficiency

$$\frac{f_{ult}k}{\rho E \alpha}$$

Values of this efficiency are also presented in Table 3.

An important consequence of thermal stress distributions is the reduction of both the effective torsional stiffness and flexural stiffness of a wing structure, this being additional to any losses resulting from a decrease in the elastic moduli. The effect on torsional stiffness has received most attention,[15] although more recently papers have been published dealing with the flexural problem.[17]

An analysis is now presented in which the influence of conductivity is indicated. The best example is a solid light alloy wing which is accelerated to M = 3·0 at 70,000 ft. after a long period of flight at M = 1·4. Instantaneous acceleration was assumed, as was also a constant value of the heat-transfer factor (h), determined for turbulent flow at the mid-chord using Ref.[3]. It should be noted that an acceleration of 25 g., a typical missile value, from M = 1·4 to M = 3·0 corresponds to an acceleration time of about two seconds. Therefore, the assumption of instantaneous acceleration should be realistic.

A finite difference method was used to determine the chordwise temperature-time variations. Hence the thermal stress distributions were obtained, with corresponding maximum drops in torsional stiffness of approximately 10 per cent and 40 per cent.

It should be emphasised that a similar analysis for other materials, e.g., stainless steel should not necessarily show the same marked influence of thermal conductivity. The

TABLE 1. Values of "stagnation" and "adiabatic wall" temperatures

Temperatures		Mach. numbers				
		1	2	3	4	5
Ambient (T)						
T = 0°C.	"Stagnation" T_H °C.	55	218	491	874	1365
T = 15°C.	From eq.(1) T_H °C.	73	245	533	937	1455
T = 15°C.	Laminar Tw °C.	64	206	428	725	1086
T = 15°C.	Turbulent Tw °C.	66	216	456	774	1160

TABLE 2. Conditions behind a normal shock moving in air (T=0°C.)

Mach. No.	Pressure Ratio	Temp. Ratio	Temp. °K.	Density Ratio
5	29	6 (6)	1,600	5·5
10	130	16 (21)	4,400	8·4
15	290	27 (46)	7,400	9·7
25	800	44 (126)	12,000	12·1

Figures in brackets refer to non-dissociated flow (see Equation 1).

TABLE 3. Values of thermal stress coefficients and efficiencies for five metals

Material	Thermal Stress Coefficient	Relative Order	Thermal Stress Efficiency	Relative Order
Magnesium alloy	16	1	105	1
Aluminium alloy	27	1	125	1
Titanium alloy	147	7	25	5
Alloy steel	350	16	10	12
Nimonic	860	40	4	30

TABLE 4. Mechanical properties of various materials

Material	Specific Strength (t.s.i.)/(lb./in.³)				Specific Stiffness (p.s.i.)/(lb./in.³) × 10^6				Thermal Stress Modulus Eα p.s.i. °C.			
	20	100	250	400°C.	20	100	250	400°C	20	100	250	400°C.
Al Alloy	335	300	90	20	95	90	70	50	220	210	175	135
Hiduminium 100	230	180	130	80	105	95	80	65	—	—	—	—
Titanium alloy	380	350	290	280	95	92	85	80	157	155	140	128
Stainless steel	210	210	200	150	110	105	100	92	270	290	310	300
Epoxy glass cloth	280	250	160	10	65	50	35	0	8	6	4	0
Magnesium alloy	260	190	90	0	95	76	50	0	180	140	90	0

TABLE 5. Physical properties of various materials

Material	Specific Gravity	Thermal Conductivity CHU/hr. ft.² °C./ft				Thermal Diffusivity ft.²/hr.				Melting Point (°C. approx.)
		20	100	250	400°C.	20	100	250	400°C.	
Aluminium alloy D.T.D.683	2·7	80	86	98	110	2·2	2·4	2·8	3·1	660
Titanium alloy I.C.I.314A	4·5	10	10	10	10	0·3	0·23	0·23	0·20	1,800
Stainless steel Jethete M 160	7·8	13	14	15	15	0·3	0·3	0·3	0·3	1,400
Epoxy glass cloth	0·1	1	—	—	—	0·05	—	—	—	600
Magnesium alloy Z5Z	1·8	65	—	—	—	2·6	—	—	—	650

value of thermal diffusivity for stainless steel (Table 5) is one-eighth of the light alloy value, indicating that conductivity might profitably be neglected in a similar example using stainless steel.

Alleviation of Thermal Effects

In the efficient design of structures to withstand thermal as well as direct stresses, consideration must be given to all forms of alleviation of thermal effects, and the weight, complexity and cost of various alternative schemes must be carefully assessed.

The input of heat into a structure is influenced by the materials used, and may depend upon the ingenuity with which the effects of radiation, conduction and convection can be employed. Obviously, there will be benefits in the use of heat-resistant materials, coatings and insulations, as well as sandwich forms of construction such as brazed honeycomb, which makes excellent use of the low conductivity of air.

It will be seen that in future structural designs optimisation will be considered from the standpoint of high-temperature materials, insulation and/or heat suppression, diversion and removal techniques. Included in the latter is the possibility of injecting a coolant fluid through a porous wall into the boundary layer, or using coverings of semi-metallic materials with advantageous evaporative or sublimation qualitites at high temperatures. All these concepts offer a tremendous challenge to the designer and it will now be appropriate to consider in more detail some of the possible methods of thermal stress alleviation. The seriousness of kinetic heating is emphasised by the results obtained by Cleaver and Thomson at the College of Aeronautics, and which are illustrated in Fig. 4.

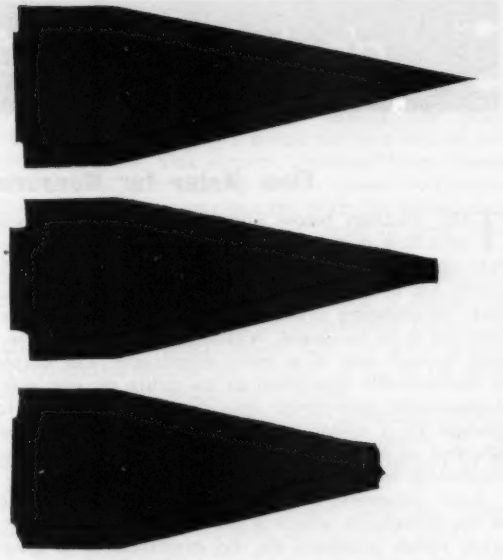


Fig. 4. Ablation of 25 deg. cone of eutectic alloy (63 per cent Sn, 37 per cent Pb) subjected to supersonic stream with stagnation temperature of 218 deg. C. Top: t = 0; centre: t = 6.25 secs.; below: t = 12.5 secs.

STRUCTURAL METHODS—The structures engineer can minimise thermal effects by designs which reduce temperature gradients within the structure and the restraint between its component members.[12, 15, 18]

To assist the former, joints between members should preferably be welded or brazed so as to minimise temperature differentials caused by structural discontinuities. Alternatively, if, say, an all-steel structure is considered (as was discussed earlier), the temperature gradients can be reduced by providing a highly conductive heat path between the hotter and cooler members.

Reduction in restraint can be obtained in various ways. Sandwich honeycomb construction, whilst having adequate shear strength, has very low extensional stiffness and even lightening holes in webs achieve a similar result.

The problem of optimum design of a conventional, uninsulated, multiweb structure at moderate temperatures has been treated,[19] and it was shown that inclusion of high thermal stresses need not necessarily imply large weight increases.

If insulation is considered on structures subjected to short time heating, both Refs. [12] and [20] contain interesting results. In the particular example of [12], the comparative merits of selected quantities of external insulation and internal cooling were investigated. The main results showed that, whereas insulation reduced the maximum thermal stress to less than a third of that in the bare structure, it provided only a short time delay on structural temperature rise. Cooling alone, however, kept structural temperatures down, but a stable condition of high thermal stress was set up, one-third greater than that in the bare structure. The combination of insulation and cooling kept temperatures down, but a high state of stable stress was again set-up, being more than one half that in the bare structure. The main result to be noted from [20] was that insulated light alloy would give a lighter structure than by using any other metal for short-time moderate heating. At still higher temperatures insulated titanium and then insulated inconels proved most efficient. In other words, insulated steels gave heavier structures at all temperatures.

AERODYNAMIC METHODS—There are several ways in which aerodynamic methods can alleviate thermal problems, most of which require the assistance of the structures engineer.

A laminar boundary layer reduces both drag and the heat-transfer factor, and a smooth surface finish can help to achieve this.

REFERENCES

1. Rubesin, Maydew and Varga. *Analytical and Experimental Investigation of the Skin Friction of the Turbulent Boundary Layer on a Flat Plate at Supersonic Speeds.* N.A.C.A. Tech. Note 2305.
2. Przemieniecki, J. *Transient Skin Temperatures and Stresses Attained in High-speed Flight.* Bristol Aeroplane Co. Ltd. Tech. Office Report 77.
3. Monaghan, R. *Formulæ and Approximations for Aerodynamic Heating Rates in High-speed Flight.* R.A.E. Tech. Note Aero. 2407.
4. Eckert, E. *Survey of Heat Transfer at High Speeds.* W.A.D.C. Tech. Report 54-70.
5. Hoff, N. J. "Comparison of Radiant and Conductive Heat Transfer in a Supersonic Wing," *Jour. Aero. Sci.* Readers Forum, **23**, July 1956.
6. Biot, M. "New Methods in Heat Flow Analysis", *Jour. Aero Sci.*, December 1957.
7. Johns, D. "Approximate Formulæ for Thermal Stress Analysis," *Jour. Aero. Sci.*, Readers Forum, August 1958.
8. Johns, D. *Thermal Stresses in Thin Cylindrical Shells Stiffened by Plane Bulkheads, for Arbitrary Temperature Distributions.* College of Aeronautics Note No. 83.
9. Meikle, G. *Summary of the Effect of Heating Some Aluminium Alloys and Alloy Steels at Elevated Temperatures.* R.A.E. Tech. Note Met. 187.
10. *Hiduminium R.R.58*, High Duty Alloys brochure.
11. Murphy, A. "Materials for Aircraft Structures Subjected to Kinetic Heating," *Jour. Roy. Aero. Soc.*, October 1957.
12. Kitchenside, A. "The effect of Kinetic Heating on Aircraft Structures," *Jour. Roy. Aero. Soc.*, February 1958.
13. Przemieniecki, J. "Transient Temperature Distributions and Thermal Stresses in Fuselage Shells with Bulkheads or Frames," *Jour. Roy. Aero. Soc.*, December 1956.
14. Goodier, J. N. "Thermal Stress and Deformation," *Jour. App. Mech.*, **24**, pp. 467-474, September 1957.
15. Legg, G., and Stevens, G. "Temperature Distributions in Aircraft Structures and Influence of Mechanical and Material Properties", *Jour. Roy. Aero. Soc.*, March 1958.
16. Budiansky, B., and Mayer, J. "Influence of Aerodynamic Heating on the Effective Torsional Stiffness of Thin Wings", *Jour. Aero. Sci.*, December 1956.
17. Mansfield, E. "Combined Flexure and Torsion of a Class of Thin Heated Wings—A Large Deflection Analysis", R.A.E. Report. Struct. 237.
18. Meyer, J. "Thermoelastic Distortion and Wing Structural Design", *Aeronautical Engineering Review*, September 1957.
19. Johns, D. *Optimum Design of Multi-cell Box Subjected to a Given Bending Moment and Temperature Distribution.* College of Aeronautics Note No. 82.
20. Dobbins, R. "The Minimum Weight of a Structure Protected Against Short Duration Aerodynamic Heating by Means of Thermal Insulation", *Inst. of Aero. Sci.* Preprint No. 773.

designer's notebook

Flow Meter for Measuring Rapid Changes in Rate of Flow

THE diagram below illustrates the working principle of a flow meter capable of measuring changes in flow rate up to 100 c/s. Two small-bore tubes from the flow meter are connected to those parts of a venturi, orifice plate or pumping system at which differences in rate of flow are to be measured. Within the instrument these tubes lead to each side of a metal diaphragm. The diaphragm is mechanically connected at its centre on one side to a displacement transducer and on the other side to the plunger of a solenoid. A flat spring of spider form is attached to the central rod connecting the centre of the diaphragm to the transducer plunger.

Axial movement of the diaphragm causes displacement of the transducer, which is fed by a 1 kc/s oscillator. The error signal produced by this displacement is magnified by a transistorised feed-back amplifier which is connected to the solenoid.

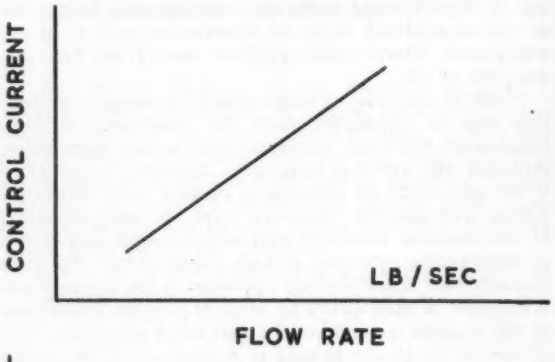
$$\text{As Flow} \propto \sqrt{\triangle P}$$
$$\text{and Force} \propto I^2$$
$$I = K \text{ Flow}$$

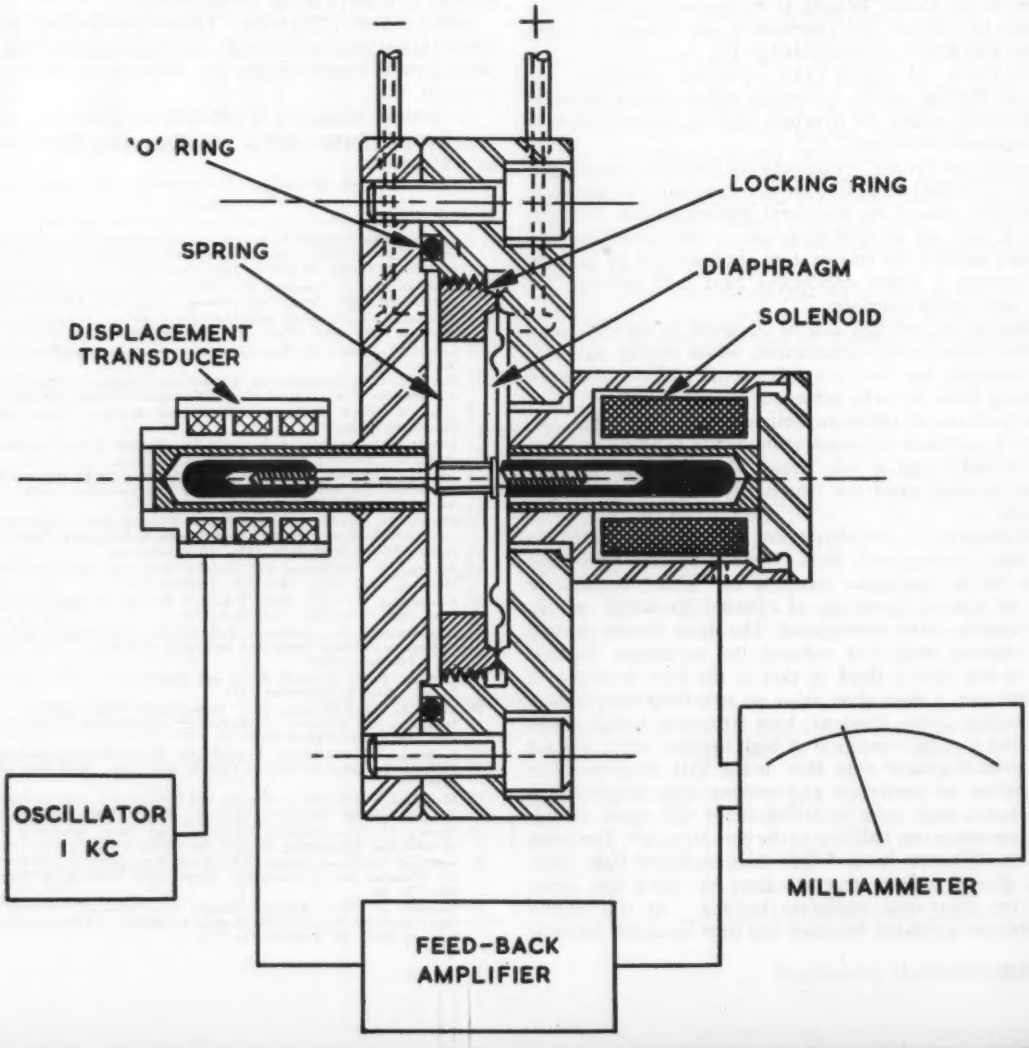
where P = change of pressure; I = current; K = constant.

From this it will be seen that the scale of a milliammeter measuring the input current to the solenoid necessary to restore the diaphragm to its original position will bear a linear relationship to the rate of flow being measured.

This form of flow meter, which is still undergoing development, is of particular value where a high response rate is required.

E. W. Ling (*Lintronic Ltd.*)





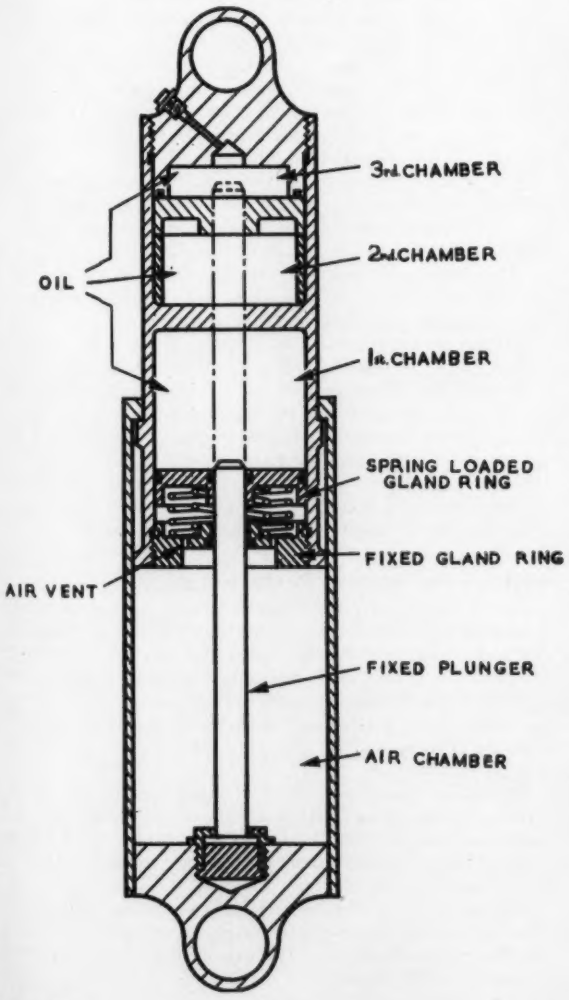
Three-stage Liquid Spring

THE sectional drawing below shows a form of patented liquid spring shock absorber which could be made to give one or more stages of resistance to compression. Three axially-spaced chambers containing liquid are situated in the upper member which slides within a lower member containing air. Fixed to the centre of this lower member is a plunger which passes first through a fixed and then a spring-loaded gland ring into the first liquid containing chamber. In the initial stage of compression, movement of the plunger causes compression of the liquid and the spring-loaded gland ring is displaced downwards; air contained between it and the fixed gland is exhausted to atmosphere via the air chamber.

When the plunger has traversed the length of the first chamber it then passes through an aperture (in which it is a close sliding fit) into the second chamber, where greater resistance is encountered. Any small amount of oil escaping from the second to the first chamber merely pushes back the gland ring a little farther against its spring. In the third chamber the plunger passes through a second close-fitting aperture without any further increase in compression of liquid in the second chamber.

The chamber volumes may be selected to give the required travel and load characteristics.

Dowty Equipment Ltd.



Compact Fluid-powered Rotary Actuator

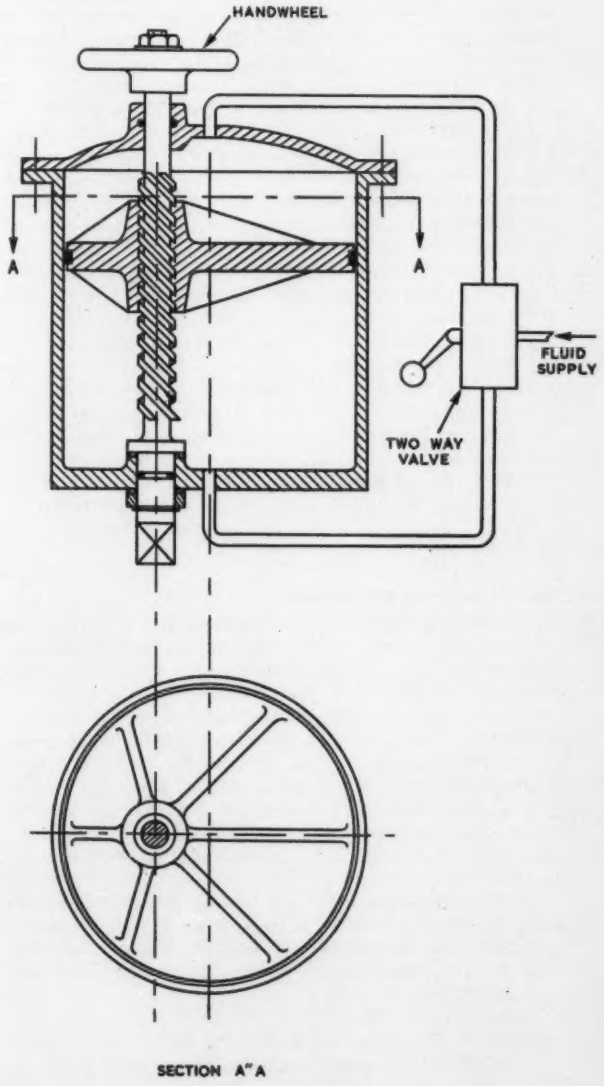
IN the customary arrangement of a screw transformer, for turning linear into rotary motion, the piston movement is transmitted by a piston rod to a nut element outside the cylinder. This element, prevented from rotating by some form of anti-torque guidance, rotates the threaded spindle as it advances along its axis. With this arrangement a total clearance length for motion, equal to three times the piston stroke, is required.

The purpose of the form of actuator semi-diagrammatically illustrated was to provide a unit of more compact size and, at the same time, make provision for manual operation if the fluid supply should fail. The piston motion is not transmitted outside the cylinder at all, as the screw spindle is contained within the cylinder.

In the embodiment of the invention illustrated, rotation of the piston within the cylinder is prevented by the eccentric disposition of the nut element in relation to the axis of the cylinder.

Unlike commercially available rotary actuators, several complete revolutions are possible for one piston stroke.

J. S. Shapiro, Dip.Eng., A.F.R.Ae.S., and R. L. Napier



WIDE APPLICATION FOR FOAMED METALS

FROM OUR OWN CORRESPONDENT

A NEW type of experimental metal foam that resembles a petrified sponge and has a density one-ninth that of solid metal has been developed by the Aircraft Gas Turbine division of the General Electric Co. At present the foaming process is still in the development stage, but successful foams have already been produced from such metals as nickel, copper and cast iron.

The new foams, called F-alloy, are expected to be particularly valuable in developing lighter and more efficient gas turbine engines. Not only is the foam metal light, but its high surface area and cell structure make it suitable for either cooling or insulating purposes. Engine tests have demonstrated the value of metal foams as rubbing seals in engine high-temperature areas. Other potential jet engine applications include labyrinth seals, high-temperature filters, thermal insulators, transpirational cooling devices and as a filler material for metal sandwich structures.

Many other uses have been conceived for the metal foams, some outside the jet engine field. Foamed copper, for example, has been proposed for large electrical equipment. In some applications, the heat generated by electricity passing through a solid copper conductor limits the amount of electricity the conductor can carry. On a pound-for-pound basis, foamed copper has the same conductivity as solid copper. However, the foamed copper has a higher electrical capacity because of its better cooling action.

Processing details are meagre, but it has been stated that the foam ingredients must be mixed carefully in the right proportions, poured into a mould, and then baked at a given temperature. The rising or foaming action occurs early in the baking process. The foams can be moulded into practically any desired shape and machined with conventional tools. The weight and strength of the foams are in proportion to their density, which can be controlled.

(*Note:* Foamed aluminium has also been developed in the U.S.A. by the Foamalum Corp.)

New Plastics Materials

Engineering information on new plastics materials and improvements in older plastics highlighted the two recently-held annual technical conferences of the two U.S. plastics societies—the Society of Plastics Engineers and the Society of The Plastics Industry, Reinforced Plastics Division.

STRONGER POLYESTERS—So-called isophthalic polyester resins, when compared with conventional polyesters, have improved mechanical strength and heat resistance. In particular, such resins have high flexural strength at elevated temperatures and good wet creep resistance. In fact, creep resistance is reported to approach that of heat-resistant epoxy resins.

The improved polyester is produced by substituting isophthalic acid for phthalic anhydride in the initial reaction producing the unsaturated polyester. Resins can be subsequently crosslinked further in the conventional way with monomers such as styrene.

Initial data on the materials were presented at the S.P.I. meeting by California Research Corp. However, a number of U.S. polyester producers now have isophthalic polyesters on the market. Such a resin is now being used in the reinforced plastic body of the Chevrolet Corvette sports car.

NEW WATER-RESISTANT THERMOSET—A new thermosetting resin has been developed for reinforced plastics. Major attributes are said to be light weight (density: 1·0-1·03 gm./cu. cm.), exceptional water resistance (moisture absorption: 0·0-0·05 per cent in 24 hr.), good chemical resistance, and excellent dielectric properties. Now in pilot-plant production by Esso Research & Engineering Corp. and designated C-oil, the resin is a copolymer of butadiene and styrene, copolymerised in such a way that the product is thermosetting in nature.

The resin can be used in the form of unfilled castings for electrical applications, as well as in glass-reinforced laminates. It is particularly well suited for fabrication in the form of glass cloth pre-impregnated laminates. It has a stable B-stage, and "prepregs" are easy to handle, have low mould shrinkage and fast cure.

FIRE-RESISTANT EPOXY—A chlorinated epoxy resin, designed for potting, casting or laminating applications where flame resistance is needed, has been developed by Jones-Dabney Co. Cured samples are self-extinguishing in two seconds, as compared with burning times of fifty seconds or more for conventional epoxy materials. Mechanical properties of the new resin are somewhat lower than those of conventional epoxies. Electrical properties are comparable at temperatures up to about 150 deg. C.

HEAT-RESISTANT ACRYLIC—Not discussed at the two conferences, but recently announced by J. T. Baker Chemical Co., is a new transparent acrylic resin which has a heat-distortion temperature of 244-252 deg. F. (ASTM 264 p.s.i. stress). This is about 10 deg. C. higher than maximum heat-distortion temperatures of conventional transparent acrylics. Designated Pl-11, the material is said to be similar to conventional polymethyl methacrylate extrusion and injection moulding grades in mechanical and optical characteristics. However, it may be immersed for indefinite periods in boiling water without affecting its transparency. It is available in limited developmental quantities.

Continuous Strand Preforming

A new "gun" for preforming glass fibre roving on a continuous basis instead of in cut fibre form has been developed by Johns-Manville Fiber Glass Inc. Use of the gun for preforms is said to (1) result in reinforced plastics parts of higher mechanical strength, (2) eliminate the 5 to 10 per cent loss in glass incurred in the chopped strand preforming process, and (3) eliminate the need for costly cutting equipment.

The gun is best suited to producing symmetrical parts. Parts as large as a 15-ft. boat have been produced; the process is not completely successful for very small, asymmetrical, sharp-angled parts because the continuous strands have a tendency to "bridge".

The device is a combination of a metering unit which controls the flow of roving to the gun, and a hand-operated shaped, preforming screen. The roving seems promising, but further work is needed.

INDIUM (In.)

Standard grade: 99·97% purity
High-purity grades: 99·999% and 99·9999% purity

GENERAL PROPERTIES

Crystal Structure	Face-centred tetragonal, A_0= 4·583A°. C_0=4·936A°
Density at 20°C.	7·3 gm/cc.=(0·264 lb./in.³)
Specific Heat at 20°C.	0·057 cal./gm./°C.
Melting Point	156·17°C. ±0·05
Boiling Point	2,000°C ± 10°
Coefficient of Linear Expansion at 20°C.	33 × 10–⁶/°C.
Thermal Conductivity	0·057 cal./cm²/cm./°C./sec.
Electrical Resistivity	
20°C.	9 × 10–⁶ ohm-cm.
Liquid (m.p.)	29 × 10–⁶ ohm-cm.
3·38°K.	Superconducting]
Temperature Coefficient of Resistance	0·00498/°C.
Specific Heat	0·0568 cal./gm./°C.
Latent Heat of Fusion	6·8 cal./gm.
Latent Heat of Vaporisation	468 cal./gm.
Magnetism	Diamagnetic
Brinell Hardness*	0·9
Tensile Strength*	380 p.s.i.
Elongation*	22% in 1 in.
Reduction in Area*	87%
Compressive Strength†	310 p.s.i.
Modulus of Elasticity*	1·57 × 10⁶ p.s.i.
Solidification Shrinkage*	2·5%
Oxide Film Formation	At room temperature a thin tenacious oxide film forms on surface and resists severe oxidisation to a temperature little above the melting point of indium. The oxide film may be dissolved in dilute HCl.
Alloying	In general, addition of indium has effect of hardening, strengthening and increasing corrosion resistance of the alloy.
Toxicity	Indium is non-toxic and non-irritant.
Formability	Highly plastic and may be deformed almost indefinitely under compression. One of the softest metals (it may be scratched by the fingernail) and will adhere to other metals when rubbed together.

* Tests conducted on the metal as annealed 1 week at 110-130°C.
† True compressive stress at 10% true strain.

MAJOR USES

SEMI-CONDUCTORS: Indium readily wets germanium and dissolves it at low temperatures. Because of its softness, it does not cause severe stresses in germanium when contracting.

BEARINGS: Impregnation of bearing surfaces permits greater retention of oil film and offers a high resistance to corrosion by acids present in lubricating oils.

LOW MELTING ALLOYS: For foundry patterns, fusible plugs, etc.

GLASS SEALING ALLOYS: Indium is capable of wetting glass for either glass-to-metal or glass-to-glass seals.

SOLDER ALLOYS: Capable of wetting most metals.

WINDSCREEN COATINGS: Tin-doped indium oxide films applied to windscreens prevent their icing and fogging and transmit 88% light.

LUBRICANTS: Non-corrosive properties and heavy-duty service.

PLATING: Electro-plating on lead, zinc, copper, tin, iron, etc.

NUCLEAR ENERGY: Artificial radio-activity easily induced in Indium, thus making it suitable for indicators in atomic piles.

Natural Indium:
Absorption cross-section for thermal neutrons: 191 Barns.

Indium 113:
(a) Possibly radioactive with 10^{14} year half-life undergoing L-capture to stable Cd-113.
(b) Cross section for thermal neutrons in $\eta\gamma$ reactions:
(i) 2·0 Barns, producing 72 sec. In-114, which decays by beta (97%, 2·05 Mev) and gamma (3%, 0·715, 0·548 and 1·27 Mev) emission to stable Sn-114.
(ii) 56 Barns, producing 50-day In-114 which decays by gamma emission (0·19 Mev) to 72 sec. In-114.

Indium 115:
(a) Naturally radioactive, half-life 6×10^{14} years decaying by beta emission (0·63 Mev) to stable Sn-115.
Cross-sections for thermal neutrons in $\eta\gamma$ reactions:
(i) 145 Barns producing 54·3 min. In-116 which decays by beta (0·7 Mev) and gamma (0·14–2·3 Mev) emission to stable Sn-116.
(ii) 52 Barns producing 13 sec. In-116 which decays by beta emission (2·95 Mev) to Sn-116.
(b) Artificially radioactive produced in uranium fission. Half-life 4·5 hr., decaying by beta (0·83 Mev) and gamma (0·34 Mev) emission to stable Sn-115.

AVAILABILITY

Metallic forms of indium are available in standard and high-purity grades as ingot, wire, ribbon, foil and sheet, powder, disc pellets and spherical pellets.

Data by courtesy of Henry Gardiner Ltd.

New Books

Handbook of Torsional Vibration. *By the British Internal Combustion Engine Research Assoc. (Cambridge University Press, £5 10s.)*

THE members of the B.I.C.E.R.A. panel are to be congratulated on the preparation of an extremely comprehensive handbook covering the subject of torsional vibration of the internal combustion engine.

The text is divided into four basic parts. Part one deals with preliminary calculations and measurements of moments of inertia and stiffness values of the engine running gear and driven machinery. Both theoretically derived formulæ and empirical data are included. A useful section is devoted to the torsional characteristics of couplings and clutches and natural frequency calculations form the concluding topic.

The engine designer is primarily interested in failure, in this case by fatigue, and part two is concerned with the evaluation and prediction of stresses set up during torsional vibration. Harmonic analysis of the tangential pressure diagram, phase angle diagrams and the effect of change of firing order, and amplitude determination at both resonant and off-resonant conditions are the main highlights of this section. Stress determination from vibration measurements and prediction of stresses at the design stage are considered. Damping factors are assumed to be of the viscous type.

It is essential, when a resonance cannot be eliminated by design arrangement, to consider methods of limiting the amplitude. Amplitude limitation thus forms the theme of part three. Explanations and theories are given of the undamped vibration absorber, the damped vibration absorber and the pendulum absorber. The Lanchester damper, with both viscous and solid friction, together with other dampers of the slipping torque variety are also considered. Some extremely useful information is given on the subject of damper design.

In dealing with the torsional vibration problem, confirmation of calculations and the gathering of design data are dependent on the accuracy of measurements made in the field. The instrumentation of vibration measurement, the topic of part four, has developed rapidly in the last decade. Modern developments described in the text include the electronic wave analyser and the use of frequency modulated amplifying equipment. Details are given of the currently available mechanical and electrical torsiographs and calibration is discussed at some length. Stress measurement by strain gauge techniques concludes this final section.

The handbook effectively combines the role of a text-book, since it deals with basic theories, and a design office tool containing, as it does, a most useful collection of design data. The text is adequately indexed and references are generously quoted. It is to be strongly recommended to engineers and designers concerned with the problem of torsional vibrations in the internal combustion engine.

W. Carnegie

Engineering Drawing and Drawing Office Practice. *By P. S. Houghton, A.M.I.Mech.E. (Crosby, Lockwood, 20s.)*

This, the second edition of a work first published in 1950, retains the original layout, with the addition of recommendations and comments based on B.S. 308:1953. Intended for the apprentice or student at a technical school, it provides a useful introduction to engineering drawing.

After the preliminary chapters on the selection of drawing equipment, draughting methods and projection, etc., in which there is a useful section on correct dimensioning, considerable attention is then given to examples of draughting in a number of different fields and the problems commonly found therein: methods of fastening, pipe drawings and power transmission, elementary gear design, jigs and fixtures, press tools, castings and machine design, with concluding chapters on drawing office organisation and checking procedure. Considerable emphasis is placed on the importance of workshop experience, and the text is copiously illustrated with practical examples of what the young draughtsman will be called upon to draw.

F.R.T.

Plastics Materials Handbook. *By Alan B. Glanvill, A.M.I.Mech.E. (Machinery Publishing Co., 5s.)*

This small handbook gives the properties of most of the thermoplastic and thermosetting materials at present in use, the forms in which they are available and the trade names by which they are known. In addition, recommendations are given on machining, together with brief particulars of the manufacturing and processing methods used. It should prove of considerable value to the mechanical engineer not generally familiar with plastics.

Preparation of Drawings for Service Equipment. D.E.F. 33. *(H.M.S.O., 7s. 6d.)*

Designed to be read in conjunction with B.S. 308 (Engineering Drawing Practice), this specification provides a standard for the preparation of drawings for service equipment by government establishments and contractors. The sizes of drawings, systems of scheduling and item numbering, are given, together with the methods of presentation of lists associated with drawings and diagrams, etc.

Dimensions for Worm Gear Units (B.S. 3027: 1958) *(B.S.I., 3s.)*

This new publication specifies the principal external and mounting dimensions for worm gear units of 4-in., 6-in. and 8-in. centre distances. Its requirements are similar to those already worked to by the gear manufacturing industry—hence their embodiment in this national standard should promote interchangeability between the products of different makers.

LETTER TO THE EDITOR

Designing Machine Tools

Sir,

Your editorial, "Machine Tool Designers of the Future" (March), is both forthright and factual, but surely at least one most important point has been omitted, that is, the question of appearance, eye-appeal, æsthetic quality, call it what you will.

Granted, the prime factor in assessing a machine tool is a measure of its capabilities, but we must not overlook the fact that the article with the best appearance makes the prouder purchaser.

If the British engineer is to successfully compete with many of the excellent designs from the Continent and the U.S.A., a new approach must be made by the machine tool industry as a whole to satisfy the ever-increasing demand for machines of good appearance and clean lines. Appearance, like ergonomics, helps the salesman, buyer and operator alike, and I sincerely believe that the manufacturer who neglects these factors can only compete in the world buyers' market by cost cutting beyond the maintenance of quality and, sooner or later, will have to change his ideas or perish.

The difficulty is, of course, that design as an art, is not taught to engineering students and apprentices and, no matter how high his technical qualifications, a design engineer who does not view things in this way has little hope of achieving anything spectacular appearance-wise.

If we are to regain our falling prestige as engineers in the overseas markets, we must immediately look to the matter of designing for eye-appeal in all our export machinery, and for the future this subject must be developed as a science, to be taught to all budding draughtsmen and designers alongside stresses and strains.

J. Rollitt

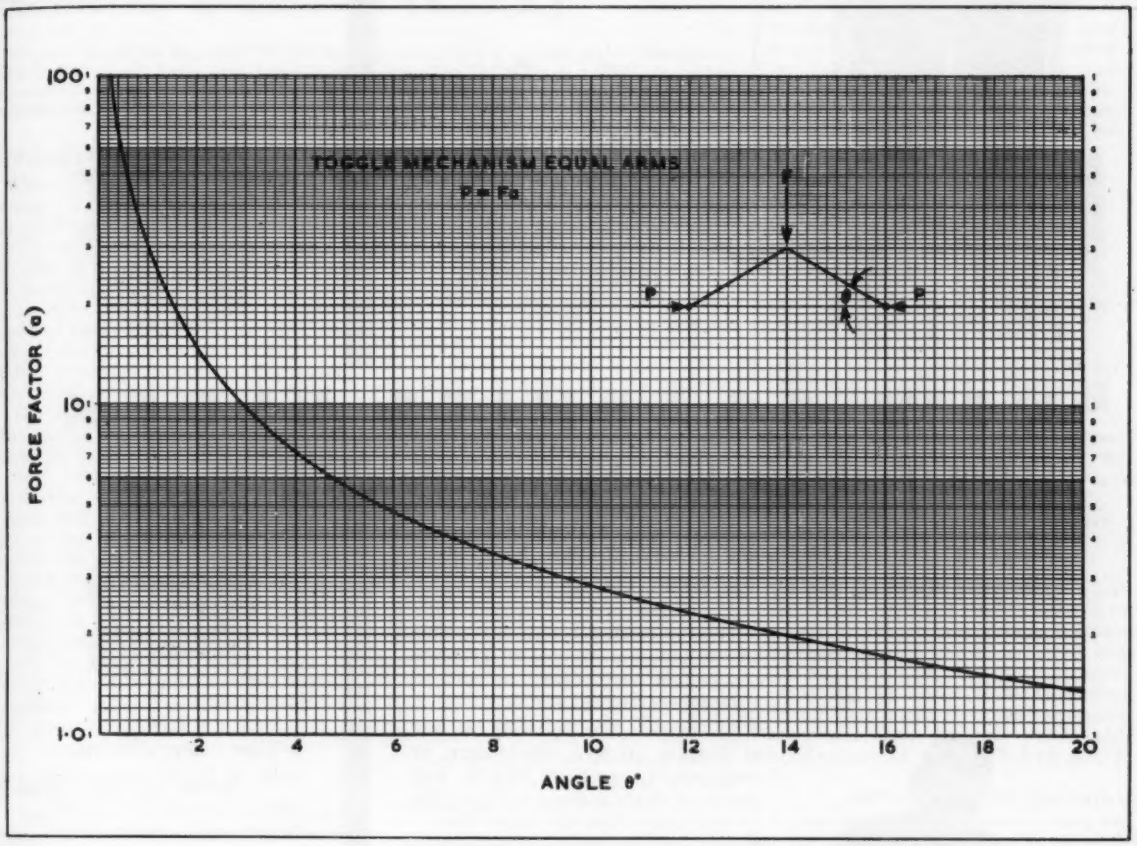
Merefield, Top Lane,
Copmanthorpe,
Yorks.

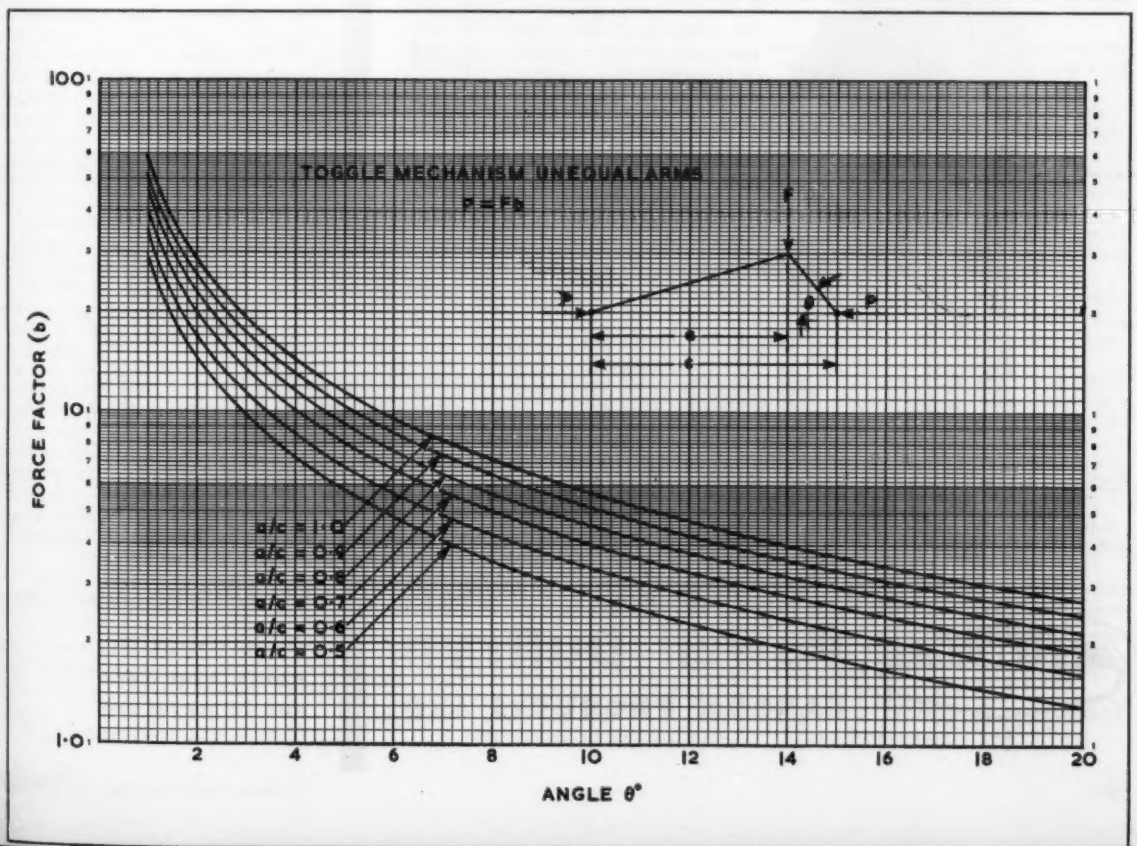
RAPID APPROXIMATION FOR

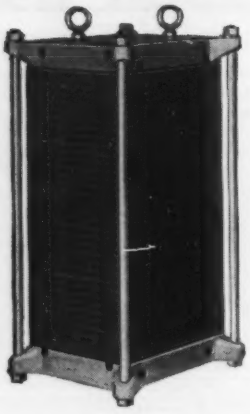
TOGGLE MECHANISMS

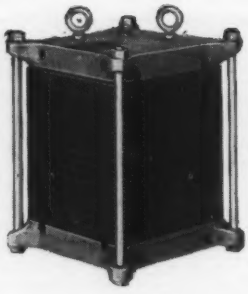
Engineering Materials and Design

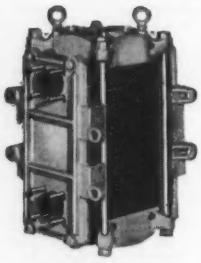
DATA SHEET No. 15







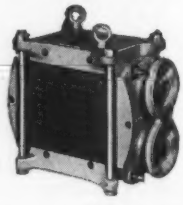




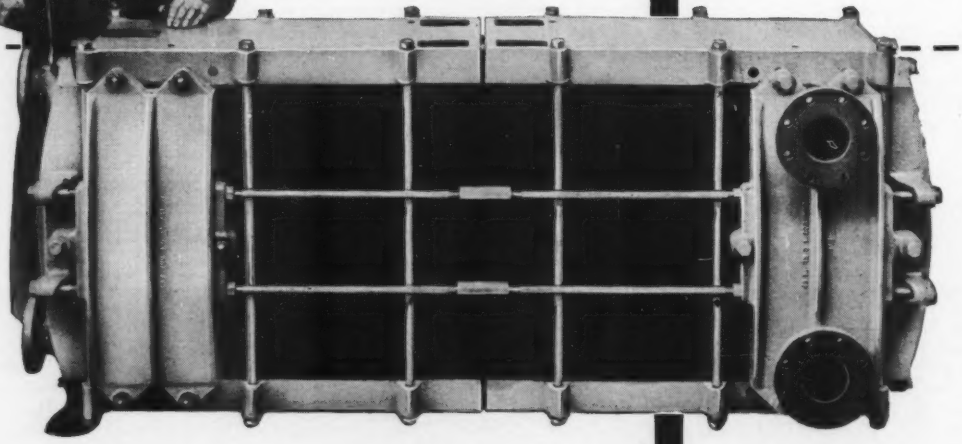
NEW GRAPHITE BLOCK HEAT EXCHANGERS

New models now provide heat surface areas from 4 sq ft to 200 sq ft

- Twenty models are now available to extend the range of graphite block heat exchangers to suit all corrosive industrial duties.
- All models are suitable for use as heaters, coolers, condensers, or evaporators, involving one or two corrosive fluids and employing single- or multi-pass flow for either fluid.
- All units are designed to provide the accepted graphite block advantages of robustness, compactness, ease of installation and maintenance.



- Tube (hole) dimensions of $\frac{3}{8}$" or $\frac{3}{4}$" or rectangular slots are available to suit heat transfer requirements or industrial scale problems.



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NEW DEVELOPMENTS AT THE ELECTRICAL ENGINEERS EXHIBITION (A.S.E.E.)

The eighth Electrical Engineers Exhibition (organised for the Association of Supervising Electrical Engineers) was held recently in London. The following is a selection of the principal items of equipment of special interest there, which were either of new introduction or being shown for the first time:

Transistor Regulator

This voltage regulator, type FV44, is designed primarily for use with single-unit self-contained alternators of rating up to 100 kVA. at 50-60 c/s and is claimed to automatically control the alternator voltage to within ±1 per cent of its rated value. The voltage regulator consists essentially of a Zener diode voltage-sensitive circuit, a transistor amplifier, a rectifier supplying the exciter field power and a stabilising circuit.

The voltage-sensitive circuit examines the alternator terminal voltage and produces an error signal when the terminal voltage departs from its normal value. This error signal, in turn, controls the exciter field through the transistor amplifier in the correct sense and degree to restore the alternator voltage. Transient negative feed-back of the exciter armature voltage into the amplifier circuit ensures satisfactory damping of the voltage recovery, following load changes.

All the components in the regulator circuit are rated to withstand tropical conditions and are said to be unaffected by vibration. B.T-H. Co Ltd.

EMD 837 for further information

Welding Current Meter

This meter is designed to measure short pulses of heavy current, as encountered in resistance welding machines. There is said to be no upper limit to the value of current that can be measured, but standard instruments have a minimum of 500 amperes and a maximum of 100,000 amperes over six scales. The minimum pulse time is 10 milliseconds, but it is claimed that pulses down to 2 milliseconds can be measured if several welds are repeated.

The instrument is intended for use with welding machines employing synchronous, non-synchronous and energy storage controls. Where phase shift heat control is incorporated, a correction factor must be used to obtain accurate quantitative evaluation of R.M.S. current, but a reading can be taken directly for checks of consistency. A standard split and hinged current transformer is normally supplied which will clamp over any bar up to 4½ in. dia. Fixed ring-type transformers can also be supplied for building into individual welding machines and any number can be switched to a meter. Hirst Electronic Ltd.

EMD 838 for further information

Two-speed Squirrel-cage Motor

A 30/15-h.p. 8/10-pole motor which was shown has a total of six leads out and is controlled by a standard switch-unit for a tapped winding induction motor.

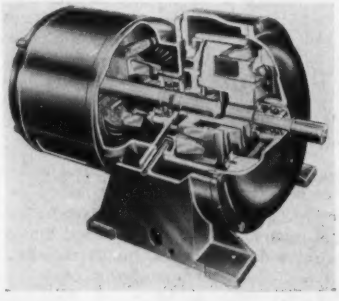
A pole-modulated tapped winding, invented by Prof. G. H. Rawcliffe of Bristol University, makes it possible to design a two-speed machine with a single tapped winding for pole numbers such as 8/10, 10/14, 14/16, 14/22 (the ratio of the pole numbers must not exceed 1·5).

Hitherto, it was necessary to wind two-speed motors having these pole combinations with two separate windings. The advantages of this new type of winding are said to be that the size of machine is considerably reduced and the performance at both speeds is generally better than that obtained with a machine having two separate windings. There is said to be no limit to the size of a machine on which this type of winding can be used. Metropolitan-Vickers Electrical Co. Ltd.

EMD 839 for further information

Eddy-current Couplings

A new range of stationary-field eddy-current couplings including water- and air-cooled types has been introduced for duties up to 50 h.p. The couplings are mounted integrally with standard flange-fixing squirrel-cage induction motors to form a compact drive. As the field is stationary, no brushes or slip rings are involved. When used with standard control gear, infinitely variable speeds over a wide range are said to be available and



many other control functions possible by adapting the control gear to particular applications. Heenan & Froud Ltd.

EMD 840 for further information

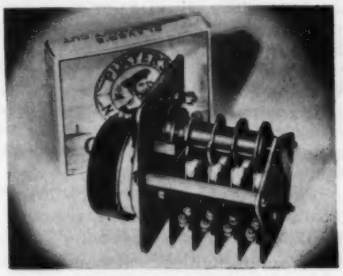
Microswitch

The V.3 microswitch is said to embody the most far-reaching improvement yet made to this switch, as the mechanism has been redesigned. The new switch is physically interchangeable with the old model and no alteration has been made to the original features. However, it is claimed that the mechanical life has been greatly increased (a minimum of 10 million operations) and that more consistent operating characteristics are obtained. It is also said that the new switch has improved resilience against shock. Burgess Products Co. Ltd.

EMD 841 for further information

Miniature Multi-circuit Timer

This unit is said to be capable of operating up to eight switches by cams and to revolve either continuously or by a special motor also supplied to reset automatically on mains failure or disconnection. The unit has been designed for mass production in order to keep down the price for large users, and it is also claimed to be easy to maintain as not



more than two screws have to be undone to remove the motor, camshaft or the switch-bank complete. Rodene Electrical Co. Ltd.

EMD 842 for further information

Electronic Slugging Unit

This is a new device shown for the first time at the exhibition and is claimed to be one of the cheapest electronic timers available. It will "slug" or delay the operation of a relay and is said to operate during any period up to 2½ minutes or with an external condenser for periods up to two hours. The unit will operate from a.c. or d.c. mains. D. Robinson & Co.

EMD 843 for further information

Designer's Diary

Apr. 20-May 2. B.I.S.R.A. "The Iron and Steel Industry" Exhib. Engineering Centre, Birmingham.

Apr. 21. R.Ae.Soc. "Structural Effects of Kinetic Heating." 1 Birdcage Walk, London, S.W.1. 9.45 a.m.

Apr. 27-30. Corrosion Exhibition. Royal Horticultural New Hall, London, S.W.1.

Apr. 28. Inst. Plant Eng. "Future Trends in Boiler Design" (A. Aston). S. Wales Eng. Inst., Cardiff. 7.30 p.m.

Apr. 29. Inst. of Metals & Iron and Steel Inst. Powder Metallurgy Group. "Theoretical Aspects of Sintering." Church House, London, S.W.1. 9.30 a.m.

Apr. 29. Inst Mech.E. "Industrial Finishing." 1 Birdcage Walk, London, S.W.1.

Apr. 29-30. I.E.E. Convention on Thermonuclear Processes. London.

Apr. 30. Inst. Plant Eng. "Metal Stitching" (N. Tinwell). Grand Hotel, Sheffield. 7.30 p.m.

May 5-16. Exhib. of New Building Materials. Building Centre, London, W.C.1.

May 11-13. Inst. of Chemical Eng. symposium. Instrumentation and Computation in Process Development. London.

May 11-14. Inst. of Fuel. Conference on Liquid Fuels. London.

May 21-30. Foundry Exhibition. Bingley Hall, Birmingham.

WHAT'S NEW IN MATERIALS & COMPONENTS

Hard Gold Plating

Electro-deposition of gold usually puts down a relatively soft coating which lacks brilliance and wears away quickly during polishing or in service. A new technique which has been developed is claimed to put down a gold deposit, controlled within ±1 micron, having good colour and brilliance and said to be nearly twice as hard as steel. Bright coatings up to 20 micron thick can be obtained without further treatment. Dennison Gold Plate Co. Ltd.

EMD 844 for further information

Transposed Conductors

The manufacture of continuously-transposed strip conductors for transformer windings has just been announced.

In the large capacity transformer field where conductors of large cross-section are required, it has been customary to wind a number of separate paper-covered conductors in parallel in one or more stacks, hand transposed to reduce copper losses in the conductor.

This procedure has several disadvantages which are said to be eliminated by the use of continuously-transposed strip conductors, where the strips are individually insulated with a polyvinyl acetal enamel, then continuously transposed in strand fashion, and finally paper insulated overall. It is said that the transformer winding can be made more rapidly and that the improved space factor permits a smaller and more efficient design. B.I.C.C. Ltd.

EMD 845 for further information

Hollow Bored Bars

A range of hollow bored bars has recently been extended to include bore diameters up to 6½ in. in bars up to 10½ in. o.d. The maximum length in the range is now 18 ft.; previous highest figures were 5 in., 8 in. and 12 ft. respectively.

Also offered are hollow bored bars or fabricated hydraulic cylinders with finished machined bores from ¾ in. to 10 in. diameter to a tolerance of ±0·003 in. Alternatively, these products can be supplied with honed finished bores from 2 in. to 8 in. diameter to a tolerance of ±0·001 in. Maximum length in each case is 15 ft.

Hollow bored forgings can now be supplied up to a limit of 28 in. o.d. and 5 tons solid weight. On lengths up to 10 ft., the forging can be bored to a blank end or with a bore stepped with varying diameters. Keeton, Sons & Co. Ltd.

EMD 846 for further information

Silvering Compound

The development of a new thermo-setting silvering preparation that has been given the code name FSP 36 has recently been announced. The preparation is based on silver in the form of finely divided flake and is specifically designed to enable surface films of relatively high conductivity to be applied by spraying or brushing to such materials as plastics, ceramics, graphite and glass. Alternatively, it may be used as a conducting cement. The only limitation on its application is that the material being coated must withstand heating to 100 deg. C., the minimum temperature necessary for curing the organic vehicle that carries the silver.

The preparation is said to have excellent covering power and the stoved film to be hard and abrasion-resistant, with an electrical resistance in the range 0·2 to 2 ohms per square. Johnson, Matthey & Co. Ltd.

EMD 847 for further information

New Silicone Compounds

Two new silicone compounds with attractive characteristics are now being made by I.C.I. Nobel Division. One is a cable rubber and the other a silicone emulsion.

Elastomer E.372 is a 70 deg. shore hardness cable rubber of improved physical properties, particularly in the elongation, which is now 225 per cent after a 24-hr. oven-cure at 250 deg. C. Because of its hardness and other good physical properties, the rubber is said to be excellent for sheathing as well as insulating cables. It will satisfy an increasing demand for a cable rubber claimed capable of indefinitely resisting ambient temperatures as high as 150 deg. C. and as low as −50 deg. C.

Silicone Emulsion M.401 is designed as a release agent in rubber and plastics moulding and in some kinds of metal moulding. It is said to be stabler at higher temperatures than the emulsions at present in use. I.C.I. Nobel Division.

EMD 848 for further information

Unplasticised P.V.C. Film

Nicotherm is a rigid p.v.c. film without plasticiser, manufactured in Germany but now available in this country. It is produced in two grades: stretched (G) and unstretched (UG). Stretched film has better tensile strength, but it shrinks by 40 per cent at temperatures of 100-110 deg. C. The stability of Nicotherm against concentrated and dilute acids, alkalis, oil, alcohols, aliphatic hydrocarbons, oxygen and ozone is claimed to be very good. The water vapour transmission rate is also said to be low. R. H. Cole & Co. Ltd.

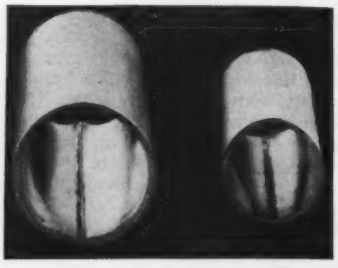
EMD 849 for further information

FOR MORE INFORMATION
about any of the products mentioned on these pages, please use the special reply card bound in this issue.

READERS' ADVISORY SERVICE
We shall be pleased to help readers who have difficulty in tracing sources of supply of materials or components.

Welded Aluminium Tube

A new process has been introduced for the production of welded aluminium tube at high speeds, and it is said to make possible a reduction in price compared with solid-drawn tube. The process, known as Thermatool, was developed



in the U.S.A. and depends on high-frequency heating of the two edges to be welded. It is claimed that, because the heated layer is only a few thousandths of an inch thick, the crystal structure of the parent metal is unaffected. Most of the metal which has been heated is forced into a scarf which is subsequently removed, leaving a smooth outer surface. Elm Engineering Ltd.

EMD 850 for further information

New Cutting Steels

As a result of research with the B.T.-H. Co. Ltd., who manufacture Ardoloy, a new grade of this carbide, known as AK, is announced. Its constituents are different from normal grades of Ardoloy, having a composition and grain structure which are claimed to have a better balance between hardness and brittleness than any existing similar material, and to be capable of withstanding severe cutting conditions, particularly when mechanical and thermal shock loads are present.

The toughness of grade AK is said to be its most remarkable feature, permitting continuous heavy metal removal usually limited only by the capacity of the machine to traverse the tool at coarse feeds and great depth of cut, using medium to low speeds. It is said to be most impressive on heavy planing, boring, plano-milling and similar operations. Alfred Herbert Ltd.

EMD 851 for further information

P.T.F.E. Insulated Wire

Two types of p.t.f.e. instrument wire for use in electrical instruments and equipment are now available for use at voltages up to 500 volts r.m.s. and 1,000 volts r.m.s. They are to Ministry of Supply (Air) Specification EL 1930, types B and C.

Applications are expected to be wide, notably in the aircraft, electronic and chemical industries. Eleven colours are available.

The wire, for use where conductor tem-

peratures of between −75 deg. C. and 250 deg. C. are experienced, has either single or stranded annealed copper wires, each silver plated to a radial thickness of not less than 0·0003 in.

The p.t.f.e. is extruded, which is claimed to permit a high degree of concentricity. Whilst the insulation is not loose, it can be cleanly stripped for connections.

Electrically, p.t.f.e. has high dielectric strength and low power factor and it is said to offer complete chemical resistance to all known solvents except molten sodium and fluorine gas. P.T.F.E. instrument wire is also stated to be non-chafing owing to the low coefficient of friction, to be highly flexible and not to harden or perish. Siemens Edison Swan Ltd.

EMD 852 for further information

Brush-applied Synthetic Rubber

The problem of applying an *in situ* protective lining or sheathing for metals and concrete exposed to unusually severe chemical attack is claimed to have been solved with the recently developed Tretoprene 2C system. A high film thickness of 15-20 thousands of an inch—equivalent to fifteen or more coats of paint—is obtained in a two-coat brush application of this protective system (on primed surfaces) which, it is said, can be applied by normal site labour. The coating is based on a synthetic rubber (neoprene) compound which has an abrasion resistance akin to that of a very tough rubber.

The Tretoprene 2C system is said to withstand attack from a wide range of chemicals used in modern industry and to be resistant to salts, mineral and vegetable oils and fats.

A protective system of this nature is believed to have wide application, not only in general industry, but also in sewerage works, on structures in marine atmospheres as well as in chemical works, paper mills and oil refineries. Tretol Ltd.

EMD 853 for further information

Sprayed Plastics Coating

A new plastics coating for metal protection is announced in the form of Organsols, a sprayable finish composed of very finely dispersed particles of plastics resin. It can be supplied in two types: (1) a smooth finish with eggshell sheen and (2) a textured finish which can be left from the spray or, by suitable texturing technique, given a grained appearance.

This dispersion has very high solids—over 60 per cent at the gun—and does not cobweb when sprayed. Because the liquid constituent evaporates rapidly, very high build is obtained without any sagging on vertical surfaces. A film deposit of 5 thou. is said to be achieved for each pass of the spray gun, with final coating thicknesses of around 10-14 thou. At this stage there is no film strength, but by baking at 180 deg. C. for 15-20 minutes the resin particles and plasticiser fuse together to form a hard, tough insoluble film. Cellon Ltd.

EMD 854 for further information

Filled Nylon

One of the newest industrial plastics available to designers is Nylatron GS nylon, which is supplied in standard stock shapes. It is a molybdenum disulphide-filled nylon composition, and it is said that moulded parts made with it have a higher modulus of elasticity and show less deformation under load than nylon 66. They are also claimed to have higher heat distortion temperatures, and coefficient of thermal expansion is approximately 60 per cent of nylon 66. One of the advantages claimed is that when parts of Nylatron GS must run dry, they operate without lubrication, and surfaces resist abrasion and demonstrate long wear in contact with metals. Chemical and electrical properties are said to be the same as those of nylon 66.

Nylatron GS is available in a variety of standard shapes and sizes, including rod, strip, tubing, tubular bar and plate. It is also available in powders for moulding. Polypenco Ltd.

EMD 855 for further information

Epoxy Casting Compound

It is claimed that the recent introduction of Double Bond Toolform overcomes the usual difficulties of applying epoxy casting resins in engineering works, for this material, supplied in many grades, is ready formulated. Thus no

skilled mixing or measuring is said to be needed.

The material is supplied in two liquids which are blended before use, the quantities of the two parts being correctly balanced so that no measurements are necessary. It is said that this resin has application in jig and tool production, as well as for models, prototypes and small-scale production. Kenilworth Manufacturing Co. Ltd.

EMD 856 for further information

Solvent-resisting Paint

Detel S/R paint is now being offered to industry as a high-quality solvent-resisting coating. It may be applied by either brush or spray, and it is claimed to be resistant to a wide range of solvents. It may be air-dried or stoved and a catalyst is normally used for best results. In the case of trichloroethylene or perchloroethylene, stoving is not essential but best resistance to other solvents can be achieved if the coating is stoved at 120 deg. C. for thirty minutes. When air-dried it is said to touch-dry quickly, but it does not reach maximum resistance to trichloroethylene until a curing period of about seven days at approximately 18 deg. C. has elapsed. After the catalyst has been added, the pot life of the mixture is some 4 to 5 days.

Of special interest to the aircraft industry will be the fact that it is claimed to be resistant to ester-based lubricant EEL 3, and if stoved for three hours at 90 deg. C., to withstand the effects of Lockheed 22 hydraulic fluid. Detel Products Ltd.

EMD 857 for further information

Plastics-covered Copper Tubing

Kuterlex tubing comprises normal high-quality copper tubing to B.S. 659: 1955 or B.S. 1386: 1957, sheathed with a seamless polyethylene or p.v.c. cover. The sheathing fits tightly on to the copper and therefore obviates the need for tedious wrapping work where this would be necessary. The tubing is said to possess all the inherent and proved advantages of normal copper tubing, but to have the added advantage of presenting a continuous protective surface to surrounding corrosive materials. Another application which presents itself is for industrial pipelines installed in corrosive atmospheres.

Extra cost of the polyethylene or p.v.c. covering is said to be completely offset by the cost of material and labour which would have been required to wrap plain copper tubing. Yorkshire Imperial Metals Ltd.

EMD 858 for further information

Versatile Adhesive

Eastman 910 is a new type of adhesive that is said to be remarkably versatile in forming rapid and strong bonds between a large number of different types of materials. This adhesive differs from conventional adhesives in that it does not set by evaporation of a solvent or by heat cure. Its most unusual property is, however, said to be the rapidity with which it forms strong bonds, this being a matter of seconds or minutes. No heat, excessive pressure or catalysts are necessary.

The adhesive is a cyanoacrylate monomer modified with a thickening agent and plasticiser. When the monomer is pressed into a thin film between two surfaces, a polymerisation reaction occurs which results in a relatively rapid set. The chemical solidifying reaction is said to take place without appreciable change in volume, a property which contributes to its strong bonding action with a wide variety of materials. Kodak Ltd.

EMD 859 for further information

Integral-sheath Thermocouple

The Integral-sheath thermocouple has been developed as a high-temperature precious-metal thermocouple assembly, which is both flexible and of small diameter. The assembly consists of an outer, flexible metallic sheath with an external diameter of approx. $\frac{1}{16}$ in., surrounding two wires comprising the thermo-elements. The thermo-element wires are insulated from one another and from the sheath by means of a compressed pure oxide refractory powder, and the resulting assembly is flexible enough to permit

EMD 790 for further information

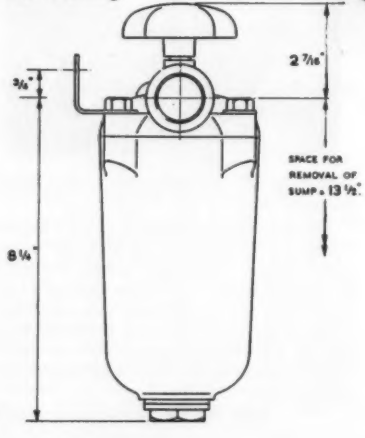
* SELF-CLEANING
* MAXIMUM ECONOMY
* MINIMUM MAINTENANCE

AUTO-KLEAN
answers your filtration problems

Self-cleaning while actually in service, AUTO-KLEAN ensures defined mesh full-flow filtration to the finest degree at any required capacity, with high and sustained efficiency throughout the life of the plant that is protected.

Large capacities relative to size save space and weight and duplex filters are unnecessary since AUTO-KLEAN are not dismantled for cleaning while the plant is working.

AUTO-KLEAN 05C and 10GA *(illustrated)* self-cleaning filters are of all-metal plate type construction and are recommended for service with oils, distillates, paints, and many other liquids at flows up to 1200 gallons per hour. They are supplied in defined meshes from 0.001" upwards and incorporate a magnetic unit to give added protection against ferrous particles.



Technical Specification Sheets giving full details will be sent on request.

AUTO-KLEAN filter anything that flows.

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AUTO-KLEAN LOLOS
AUTO-KLEAN KOTON
AUTO-KLEAN WYMESH

being formed round a diameter, equal to four times that of the assembly, without damage. The assembly is said to be completely resistant to thermal shock. Engelhard Industries Ltd.

EMD 860 for further information

Miniature Servo Motor

Servo motors, measuring only $\frac{3}{4}$ in. in dia. and $1\frac{1}{2}$ in. in length, which have

been developed from R.A.E. specification EL.1872, are now available in two versions. The standard type requires a 26-volt supply to each phase, or a 26-volt single-phase supply with a 1·5 m.f. tuning capacitor, the germanium transistor version incorporating a 26-volt reference winding and a 20-volt centre tapped control winding. Operating frequencies in both instances are 400 c/s. Minimum no-load speed is 9,000 r.p.m. and minimum stall torque is 8 gm./cm^2. The stainless iron stators are fully encapsulated and rotor laminations are stamped from corrosion-resistant materials. Smiths Aircraft Instruments Ltd. **EMD 861** for further information

Multi-contact Relay

Up to ten contact units can be provided on a new comb relay that is now on the market. The new relay is a development of the standard 3000-type relay as used by the British Post Office. It has been designed to give a mechanical life of 100 million operations without need for readjustment. The manufacturers consider that the chief advance in the new design is the replacement of the spring-set lifting pins by a lifting comb of synthetic resin-bonded paper which bears directly on the metal of the armature, without the use of keramot lifting studs. The relay can be used on normal mains voltage up to 250 volts as a result of replacing the metal lifting studs by the synthetic comb. Spring-sets are available built-up from any combination of make-and-break, make, break and changeover actions, up to a maximum loading equivalent to ten make actions. Siemens Edison Swan Ltd.

EMD 862 for further information

Reversible Sequence Controller

A new synchronous multi-circuit timer, which can be driven both clockwise and anti-clockwise, is announced. By energising one of the two self-clutching motors with which the timer is fitted, that motor clutches on to the camshaft and drives it in one direction only. Energising the other motor drives the camshaft in the opposite direction. The unit, which can have up to twenty-four fully adjustable twin cams, is also made with two motors at one end (one being shaded pole to give reverse rotation) and with a variable resistor fitted to the free end of the camshaft. This can be connected to re-balance a bridge when the correct number of heaters, pumps or the like have been switched on to give the rate of correction called for by the condition that unbalanced the bridge. D. Robinson & Co.

EMD 863 for further information

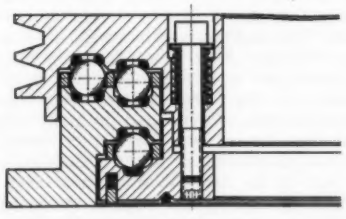
Level Controller

The Pneutronic on/off level controller provides an output air pressure suitable for operating a standard pneumatic control valve. The instrument can be used for controlling the level of solids or liquids which may be at high temperatures, high pressures or under corrosive conditions. A robust electrode is the only item in the container and there are no floats, pivots, gears, diaphragms, etc., to become clogged or worn. The equipment is fully transistorised and operates from a supply of 12 volts d.c. Fielden Electronics Ltd.

EMD 864 for further information

Wire Race Anti-friction Bearings

The section drawing illustrates the constructional principle used in a range of anti-friction wire race ball bearings, available up to 13 ft. dia. in one piece and up to 45 ft. in segments. They are said to be suitable for use as slewing



rings carrying axial loads up to 1,000 tons or even more, or as continuous bearings where surface speeds do not exceed 65 ft./sec. Internal or external spur gearing to suit individual requirements can be directly machined on to one of the rings to accept a drive for the rotating machinery.

In these bearings the rolling elements run on high-tensile spring steel wires, which are seated in accurately machined grooves. This avoids the costly grinding necessary to rectify distortion on large-diameter rings after flame hardening, and enables the bearings to be easily and precisely adjusted to eliminate play. The rolling elements of the bearings are kept at their correct pitch by cages, separators or spacer balls, according to the load/duty conditions. Roballo Engineering Co. Ltd.

EMD 865 for further information

Multi-circuit Switch

Special features of the A150 switch, a slow make-and-break on-load switch, are that the contacts are open to visual inspection and the switching sequence can be removed for servicing without dismantling the switch. Fixed contacts can be mounted anywhere on the bar so that creep distances can be increased for high-voltage applications. The fixed contacts have silver contact faces $\frac{1}{32}$ in. thick and the switch, for off-load duties, is rated at 300 amps. per moving contact. Austinlite Ltd.

EMD 866 for further information

Apparatus Bushings

A new range of bushings has been introduced to meet North American (NEMA/CEMA) specifications. They are designed as a standard interchangeable oil circuit breaker and transformer bushing and are applied for all standard ratings from 8·66 to 69 kV., 1,200 amps. In these bushings there is no conservator head and a spring washer assembly reduces the short air length. The insulating core is manufactured from a grade of bakelised paper in order to provide high thermal stability and low dielectric loss characteristics, plus good mechanical strength and resistance to moisture. Thin metallic foils are inserted during the wrapping process to provide conducting layers for controlling both axial and radial stresses. Permali Ltd.

EMD 867 for further information

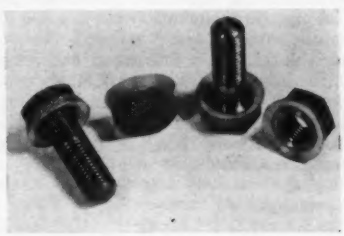
New Range of Thermistors

A range of thermistors, or thermally sensitive resistors, based on four different materials and available in a variety of shapes and sizes, is announced. They are made from intimate mixtures of metal oxides according to classical ceramic methods. It is claimed that the resistance value of a thermistor can drop more than a hundred-fold over the temperature range 0-150 deg. C. and this renders them suitable for many interesting applications. Five of the types available are said to be suitable for temperatures up to 150 deg. C., and the sixth type for 250 deg. C. They are available as discs, rods, bars, washers or beads, and can be supplied with soldered leads. Plessey Co. Ltd.

EMD 868 for further information

Waterproof Bolting

The incorporation of a plastics sealing skirt in a new range of steel nuts and bolts is claimed by the manufacturers to make possible effective moisture sealing of bolted assemblies in light alloys. In addition, the presence of a non-conducting gap between the metals greatly reduces galvanic corrosion



effects. A considerable bearing area of steel at the base of the nut and bolt head is still retained and it is therefore said to be applicable to close tolerance bolts where a plastics washer would not be permissible. It is claimed that bolted assemblies in magnesium alloys show a striking reduction in corrosion when these nuts and bolts are employed. Magnesium Elektron Ltd.

EMD 869 for further information

Miniature Instruments

A new range of panel-mounting 240 deg. scale miniature instruments, having dials 2 in. and 2½ in. in dia., is announced. They have been developed specially for use in the electronics industry and in particular for telecommunications equipment, measuring and test gear, and for electronic process control gear. A degree of accuracy for the 2½-in. dia. instruments of ±1 per cent is claimed. Nine 3½-in. scale instruments can be mounted in a 6½-in.-square panel space. They are available in either moulded plastics or sealed die-cast metal cases. Crompton Parkinson Ltd.

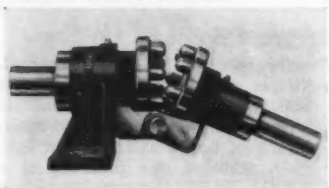
EMD 870 for further information

Rope Tension Gauge

For measuring the tension of overhead wires, tensioning ropes, traction conductors, aerials, etc., a new form of tension meter enables measurements to be made easily and rapidly without interfering with the installation of the wire or rope. The measurement relies upon the application to the rope of two fixed supports, between which is located a movable member. If the latter is applied to the rope with a given pressure, it will experience a deflection whose amplitude is proportional to the tension in the rope. The value of the deflection is then measured accurately by means of a calibrated dial gauge. Tensions of from 440-3,300 lb. can be measured, it is said, in wire ropes or cables from $\frac{5}{32}$-½ in. dia. Addison Electric Co. Ltd.

EMD 871 for further information

Remote Control Joint



The Lineta Uni-Joint has been developed for rotational movement and for the remote control of stop cocks, valves, steering, etc., at permanent or variable angles. Both bracket and flange types of mounting are available, in sizes ranging from ½ in. dia. to 1½ in. dia. An advantage claimed for these joints is that drives are possible for 360-deg. trunnion movement with pin angles ranging from 0-90 deg. Standage Power Couplings Ltd.

EMD 872 for further information

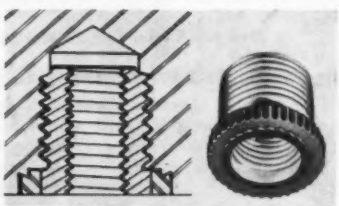
Boiler Water Dosage Unit

To maintain a constant level of treatment concentration in individual boilers and at the same time make treatment foolproof, a range of dosage units suitable for use in conjunction with any slow double-acting feed pump has been developed. They are said to be unsuitable for the small high-speed electrically-driven feed pump. The units are actuated by the reversal of hydraulic pressure which occurs in the feed pump barrel with each change of direction of travel. A piston within the dosage unit is caused to move through its full stroke, this movement operating the feed ram. A fine screw adjustment regulates the amount of treatment delivered. It is not necessary to interfere with the operation of the feed pump. Houseman & Thompson Ltd.

EMD 873 for further information

Metal Inserts with Lock

The Rosan permanently-locked studs and inserts are similar to conventional threaded inserts except for the addition



of a serrated collar. Holes to receive the inserts are step drilled to receive the collar. The stud or bush insert is first screwed into place. The lock ring is then placed over it so that the inner serrations of the ring engage with the serrated collar of the stud or insert and is then driven into the parent metal. Although the stud or insert is thus made a part of the parent body, it is a simple matter to remove and replace the insert with an identical or larger unit. It is claimed that the installation in no way exerts stress or distorts the parent metal, as the teeth of the locking ring act as true broaches. This type of insert is stated to be particularly suitable where units of soft metal must be continually dismantled. Instrument Screw Co. Ltd.

EMD 874 for further information

New Elevator and Conveyor Chain

The Bloklink chain, a new design of link assembly, is composed of one long and two short links. Advantages claimed include the following: the same size of chain is used for all widths of elevators; there is no tendency for the chain to cant on the skidder bars on account of the wider flats; assembly can be carried out on one chain at a time; buckets can be fitted without disturbing the chain; and they can be fitted into existing elevators of the multi-link type, increasing their capacity by 100 per cent or more. Automatic Coal Cleaning Co. Ltd.

EMD 875 for further information

High-pressure Flexible Hose

For the conveyance of gases and fluids at working pressures up to 400 p.s.i., a new 1¼-in.-bore hose, which is reinforced by three high-tensile steel braids, is announced. The use of nitrile rubber for the seamless inner lining is said to enable it to carry nitrogen, mineral and vegetable oils, petrol, kerosene and coolants. The outer cover, of abrasion-resistant neoprene, is said to be spark-proof and to resist oil, steam and exposure to sunlight. Operating temperatures for liquids or gases are claimed up to 130 deg. C. with ambient temperatures from −30 deg. C. to +100 deg. C. The metal end fittings are swaged on to the rubber hoses, forming an indented pressure seal. Dunlop Rubber Co. Ltd.

EMD 876 for further information

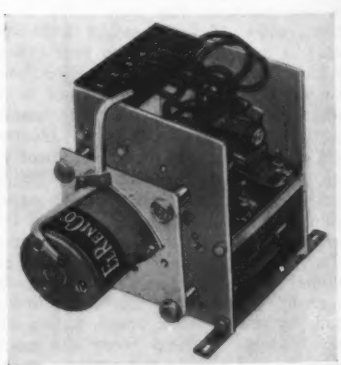
Unchokable Valve

The Sala valve, intended for handling pulps and slurries, is operated by hydraulic pressure in the annular space surrounding a rubber plug, through which the fluid passes. The even constriction of the central passage is claimed by the manufacturers to be unblockable. A manually-operated hydraulic pump can be provided, a pressure gauge providing a reliable indication of the degree of closure. One or more valves can be controlled from a central point. Neldco Processes Ltd.

EMD 877 for further information

Mercury Tube Timer

What is claimed to be an entirely new type of timer has recently been introduced in which the motor-driven camshaft operates directly a number of tilting mercury tubes. These mercury tubes, instead of conventional contacts, permit frequent switching of highly inductive



loads up to 30 amp. at 440 volts a.c. or 220 volts d.c.

The timer, called type SAT, is said to be capable of continuously repeating a predetermined sequence of operations or it can stop after a single complete timing cycle if one of the mercury switches is wired in series with the motor of the timer. It is most suitable for direct switching of highly inductive loads, with the contact arcing occurring inside sealed mercury tubes only. Electrical Remote Control Co. Ltd.

EMD 878 for further information

News of Industry

The **Aluminium Development Association** has launched an open competition for the design of aluminium street lighting columns. It is intended to encourage the evolution of good designs (taking into account appearance, economy of construction and the advantage of aluminium) and the wider adoption of such lighting columns in the U.K. Closing date is July 1 next. A total of £475 is offered in prizes.

A new subsidiary has been formed by the B.S.A. Group with the title of **B.S.A. Metal Powders Ltd.** Sintering powders have been produced by the group's research centre for some time past and the new company has been created because of the growing volume of this business. The powders were originally intended for another B.S.A. subsidiary, Metal & Plastic Components Ltd., but output has now outgrown their requirements.

British Resin Products Ltd. announce that the price of Rigidex high-density polyethylene has been reduced by up to 3d. per lb.

Activities of **Panelac Ltd.** are now integrated with those of its parent company, B.I.C.C. Ltd., within whose framework it will now operate as a heating division.

To ensure interchangeability of moulds between injection moulding machines made by different manufacturers, without hindering design developments or individual needs, a specification has been drawn up by the **British Plastics Federation** for mould fixing centres on injection moulding machines.

Sixteen papers on subjects of major importance to the plastics industry are to be presented at this year's **International Plastics Convention** in London next month. With "Developing Fields" as their theme, the papers fall under general headings of polyolefins, material developments, design trends, recent developments in glass reinforced plastics, expanded plastics and extrusion.

A special production section of this year's **St. Erik's Fair** in Stockholm (September 2-13) will have one part devoted to "Anti-corrosion Exhibits". The organisers of the British section (Trade Fairs & Promotions Ltd.) have announced that they are planning to make a particular feature of Britain's progress in this field.

Mr. G. F. R. Fielden, director of research of Ruston & Hornsby Ltd., has been elected a Fellow of the Royal Society.

The industrial group of the **Atomic Energy Authority** has been reorganised to two separate sections: the development and engineering group, and the production group.

The industrial design and engineering consultants division of Southern Drawing Services Ltd. is now operating under the name of **K. A. Hardiman & Partners**. The tracing, technical illustrating, photocopying and drawing offices supplies departments of Southern Drawing Services are not affected.

The lending library of the **D.S.I.R.** has started to collect Chinese scientific literature. About 150 Chinese periodicals are now on regular order.

An important step towards automation in the tyre industry is the introduction by **Dunlop Rubber Co.** of new electronic machinery, operated on a time-temperature basis to control the mastication of crude rubber and the subsequent mixing of various ingredients.

Hoover Ltd. are acquiring an additional 180,000 square feet of accommodation near Merthyr Tydfil as part of a big expansion programme planned by the company in South Wales.

Inquiries dealt with by the information section of the **Birmingham Engineering Centre** totalled more than 4,000 last year, a third more than the previous year. Attendance figures were over 70,000.

Chas. H. Windschuegl Ltd. have been appointed U.K. sole agents for the range of Beverol motor and industrial oils and greases manufactured in Holland.

Wolf Electric Tools Ltd. have created a new post of technical liaison officer, to be filled by Mr. Edward Patterson, to deal with electric tool research and development. In addition to internal technical committee work, he will represent the company on British and international technical committees.

The second international conference on operational research organised by the **International Federation of Operational Research Societies** will be held in Aix-en-Provence from September 5-10, 1960.

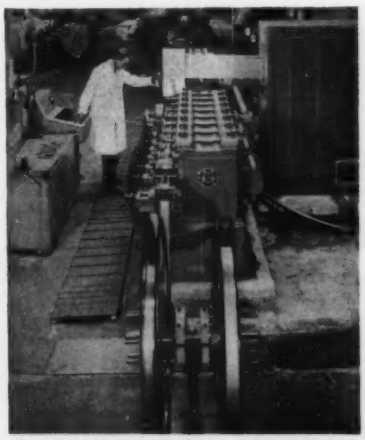
Simmonds Aerocessories Ltd. have announced the formation of a Belgian subsidiary to handle the company's range of self-locking nuts and spire speed nuts.

The seventh heat exchanger destined for the Bradwell nuclear power station was recently launched by **Head Wrightson & Co. Ltd.** It is over 90 ft. high and 20 ft. in diameter, with a weight of 200 tons. One of the most striking features of its construction was stress-relieving after welding the final assembly. To bring the entire vessel to a uniform temperature of 630 deg. C. for this purpose, the outside was completely lagged with thick insulating blankets and the heat applied to the inside by a battery of radiant heaters.

The growing importance of pneumatics and hydraulics in industry is reflected in the announcement of the formation of a **Fluid Power Association.** Its aims will be mainly to promote the correct application of this form of energy and to consider the education of industry in which this may be utilised.

The inaugural meeting of the Association is to take place on October 16 during the period of the forthcoming Pneumatics and Hydraulics for Industry Exhibition and convention at Alexandra Palace in London.

Permali Ltd. announce reductions in the price of Permaflon p.t.f.e. by an average of 10 per cent.



Recently seen in this country for the first time is this equipment employing the Thermatool process for the production of aluminium tube from strip by means of high-frequency welding. Economy is the main advantage of the tube, which is being marketed by Elm Engineering Ltd. (For details, see "What's New in Materials".)

Imperial Smelting Corporation have announced that they have now ended their investigations for the U.K.A.E.A. into thermal reduction methods of producing virgin beryllium metal, and a new plant for this is being installed at Avonmouth.

The first stage for the production of limited quantities of nuclear-grade beryllium will be in operation by the end of this year; the second stage involves considerable expansion and will be determined by the demand for beryllium primarily in connection with the development of advanced gas-cooled reactors.

A recent development introduced by **Thomas Bolton & Sons Ltd.** makes it possible for the firm to offer end-rings, rolled as rings, up to 7 ft. diameter. Rotor and stator end-rings are made by the company in high-conductivity copper, arsenical copper or aluminium-bronze.

The **Institution of Mechanical Engineers** have announced that the 1958 James Clayton Prize has been awarded to Mr. W. M. Heynes and Sir F. Ewart Smith.

EMD 793 for further information

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Casting Design causes many headaches because it is so dependent on foundry practice. This creates many problems for the Designer. The new MEEHANITE Casting Design Bulletin deals with these problems. It shows how the Design Engineer and the MEEHANITE Foundry can work together to get better Castings at reduced cost. MEEHANITE offers the Engineer the advantage of a dependable casting material on which he can base his designs with confidence. This is achieved by control over . . . . Casting Soundness, Metal Properties, and Dimensional Accuracy.

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